History of Communications-Electronics in the United States Navy

MEN WHO IGNORE THE PAST ARE
DOOMED TO RELIVE IT . . .

SANTAYANA

History of Communications-Electronics in the United States Navy

with an Introduction by

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Dedication

This work is dedicated to the officers and men of the United States Navy and to the civilian scientists and engineers whose combined efforts contributed so much to the development, first, of radio and, then, of electronics; and who provided our fighting forces with a superiority in the art that greatly contributed to our victories in the wars of the Twentieth Century.

Among all these it is necessary to single out one individual, Rear Admiral Stanford C. Hooper, USN, for his endeavors to bring discipline out of chaos and for his efforts in making America supreme in radio communications. In tribute to him, the following verses by an unknown author are reproduced.

In olden days—those were the golden days—
Would you hold converse with your friend "YE"
At Washington, you let the Fleet rave on,
And chatted gayly with him at the key,
Not caring to disregard all scheme or plan,
You opened up with "Here's a note, old man,"
But wireless to-day runs on a different plan.

It's Hoops, Old Hoop,
He changed those easy ways.
Order rescinding order keeps us in a daze.
If you want to know what gink
Put social wireless on the blink
It's Hooper, old Hooper, he's the goop.

Time was when, on a battleship, thoughts tender might intrude
Of sweethearts, even wives, who wept ashore,
"Just ask the Chief at NAM to phone this up for me, "———
This was the password, but it is no more.
The Postal Clerk computes the station charge—and gets it wrong,
The C.O. then endorses it, and maybe before long
Marconi condescends to forward love's eternal song.

It's Hoops, that's why,
Who other could it be?
He is the man who owns the copyright on QRT
If you really want to know
Who put "I owe" in "Radio"
It's Hooper, old Hooper, he's the guy.

The conning tower thru its narrow eyes surveys the scene
And feels itself sunk to a storeroom's state.
With switchboards, relays, tuners, keys, in all available space,
There seems no chance for things of lesser weight.
Such minor apparatus as control of helm or speed,
A super-Hooper-dreadnaught of course could never need.
Install! Install! There yet is room! Prove, prove, the Newer Creed.

It's Hoops (You knew it?)
'Tis his the scheme, of course.
Should not the brain have full control o'er bowel-hidden force?
On, on to Victory!
Press, press, the fluent key!
And Hooper, old Hooper, He will do it.

When Giant and Athletic meet before—a countless throng
To battle for a name—and many yen;
When from the far-flung bleakness of Cape Cod the whisper comes
Of tiny happenings in the world of men,
Whose hand directs the order that bids tactics bide apace,
As inning after inning flings its record into space,
Or T.T. tells the outcome of the 1916 race?

It's Hoops, he did;
The C. in C. may sign,
But when the bets are paid in coin, cigars, or even wine,
Well, well, the wardroom knows
To whom the credit goes.
It's Hooper, old Hooper, good old kid.

When on the dim horizon line a mighty warship lies,
Then moves, responsive to a hidden sign,
Harmonious with her sister ships that dot the distant deep,
To form as one in one manoeuvered line,
Whose years of earnest effort made such ordered actions show,
And prove by demonstration the worth of radio,
Till even the prejudice of years must needs admit it so?

It's Hoops! His ways
At last have gained their goal,
The flagship reaches out across the waters to control,
In unity complete
The Ship yields to the Fleet
And Hooper, old Hooper, deserves the praise.

Preface

SINCE THE PERIOD covered by the work is that in which electronics, for the most part, was primarily a system of radio communications, it is fitting to quote a statement of Adm. Forrest P. Sherman, USN, which was made shortly after he became Chief of Naval Operations:

> Successful communications systems do not just happen. They represent the combined skills of the engineer, the craftsman, the technician, and the operator. They reflect the countless hours spent at drawing boards and in the development laboratories of a vast electronics industry, the painstaking work of artisans and trained installation teams, the carefully drawn plans of the tactician, and the proficient hand of the operator who ultimately mans the controls.

Radio was developed as a result of the intense desires of men to exchange intelligence as rapidly as possible over long distances without physical interconnections. At its birth, like human beings, it was an infant, limited in its own capabilities. In fostering its growth, scientists and engineers sought better means of propagation of waves, and the detection and amplification of the signals imposed upon those waves, as well as a better understanding of their actions in traveling from the source of propagation to the point at which they were received.

Early in these studies and efforts to improve the distances the new mode could cover, the vacuum tube, the heart of electronics, was invented as a means of detection. For almost a decade it was considered inferior to other means of detection and its uses for other purposes remained undreamed of. Another decade passed before it assumed its present major importance in radio communications, and still another before its almost infinite possibilities were realized. During these years it was constantly improved and made into a rugged and reliable tool.

It was only proper that the United States Navy, fresh from a war in two hemispheres, should take an active interest in the early development of a means of communication which might reach its men-of-war at sea.

The chapters of part I narrate the Navy's effort to prevent monopoly, improve equipment, and to achieve orderly regulation of radio to the end that it might serve mankind.

Part II relates the usage and improvement of radio during World War I and the years that followed, and of the Navy's responsibilities in the radio communication field during this period. It relates the effort to establish a Government monopoly following the war and the failure of this which directly led to the formation of American operating companies which assumed world leadership in the field. Towards the end of this period commercial broadcasting became of major importance in the field of radio after its advent had been brought about as a result of the Navy's support of the American radio industry in the improvement of the vacuum tubes. Higher frequencies became usable for covering longer distance with greatly reduced transmitter powers. Their usage was hastened by Navy and amateur cooperation and by the deductions of naval scientists as to the action of waves of these higher frequencies.

The final part continues the narrative through World War II and contains the history of the Navy's development of such electronic systems and devices as radar and its allied equipment, sonar, drones, and the proximity fuse. It describes the use of radio as a communication system and the improvement in equipment in the early part of this period to the point where the Navy possessed the most reliable and farflung system in the world. It relates the failure to continue research in this field, as a result of this, and its effect upon available equipment in World War II. It tells the success in overcoming this, the development of improved equipments during hostilities, and the problems of usage during a war which required such a large number of worldwide channels that it became necessary to develop the use of the spectrum's hitherto unthought of frequencies.

The author desires to express his appreciation to the hundreds of persons who assisted by supplying materials, to the authors of the numerous books and articles in periodicals listed in the bibliography. He especially desires to thank the personnel of the Electronics Division of the Bureau of Ships, particularly to Mr. Mark Swanson, and the Communication Division of the Office of the Chief of Naval Operations. He is deeply indebted to Rear Adm. J. B. Heffernan, USN, who was instrumental in activating the project and to Rear Adm. E. N. Eller and Capt. F. Kent Loomis, USN, and the personnel of their offices, for their forbearance during the course of the project.

The able assistance of Capt. Ferdinand Fisher, who did the writing of the preliminary manuscript of part I and who, with the able assistance of Miss Mariam Braeger, collected the major portion of source material, is gratefully acknowledged. Finally, it is desired to express thanks to Mrs. Richard N. Rivers of Brandon, Vt., who so painstakingly typed the numerous preliminary and final drafts of this work and to Mrs. Anne M. Vezzi and Mr. L. P. Eckenfelder who rendered invaluable assistance for all those necessary arrangements for its publication.

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Captain, USN (Retired).

Introduction

SOME YEARS AGO, Naval War College publications reminded us that Communications is the *handmaiden of operations*. While this appears obvious, there is no sounder lesson for a naval officer. From single ship, to force, to fleet, to Navy Department—all through the command echelon—effective coordination and ultimate operational success depends upon efficient communications. Therefore, when the Director of Naval History asked me to prepare the introduction to this history of electronics in the Navy, I was pleased to accept. It affords me opportunity again to express my appreciation to those who made possible the reliable, rapid, and secure communications which were essential to the successful prosecution of World War II in which operations covered the many millions of square miles of the Pacific.

Upon assuming command of the U.S. Pacific Fleet on 31 December 1941, I found a well-functioning communication system capable of great expansion. Could it expand rapidly enough to handle the far-reaching demands suddenly thrown upon it? It could and did, to my great satisfaction. Large quantities of electronic equipment and increasing numbers of installation and maintenance personnel began to flow to Pearl Harbor from the Electronics Division, Bureau of Ships, directed by Commodore Jennings B. Dow. At the same time, the Communications Division of the Office of the Chief of Naval Operations, under Rear Adm. Joseph R. Redman, supplied trained operators. Thus, the Pacific Fleet Communications Officer, Captain, later Rear Adm. John R. Redman, could expand Pacific Ocean area communications to meet all operating, logistic, intelligence, and other command requirements. This gigantic task was accomplished so efficiently that the Pearl Harbor headquarters was able to exercise complete and effective control of the operations of the far-ranging forces on, under, and above the sea. The radio silence usually imposed upon the forces afloat made absolute confidence in the integrity of our communications system a matter of paramount importance. This confidence was earned and well merited.

In the last year of the war when an advanced CINCPAC headquarters was established on Guam, Commodore E. E. Stone, later rear admiral, relieved Captain Redman and administered fleet communications in the same outstanding manner. To those officers and to all the people who served under them, civilian and naval, who made possible the growth and operation of the all-important communication system, I repeat my thanks for a vital assignment well done.

The marked success achieved by naval communications in World War II was not happenstance but was the fruit of long years of endeavor. Since the dawn of time man looked for better means to communicate over greater distances with speed and accuracy. To "pass the word" when beyond voice range, he learned to beat out his message on a tree trunk or drum head. Smoke and fire beacons gave him visual signals. He used swift runners to carry news in the days of classical Greece, and swift horses for the colorful Pony Express in the American West before the coming of the telegraph.

Until the present century, a ship's isolation was complete once she navigated out of port and sailed over the horizon. Of course, ships in company or in passing "spoke" each other by voice hail, or signal flags by day, and lanterns at night. But once at sea, orders or instructions from higher commands not in company could not be easily altered. For want of communications, major battles have been fought after peace treaties were signed.

For centuries the ocean was both the great water highway of the world and a silent barrier. Radio raised the curtain to a vast and universal change. With the installation and perfection of the miracle of instantaneous wireless telegraphy, a radio-equipped ship would never again be totally cut off from the land.

The U.S. Navy, in keeping with its traditional scientific leadership, early recognized the impact of radio on naval operations. Only by such means of communication could far-scattered forces be effectively directed. Adm. Bradley A. Fiske, while a lieutenant, experimented with "electronic communication" on naval vessels in 1888, many years before Marconi's successful application. During Fiske's investigations, he discovered the principles of degaussing ships as a protection against mines (used widely in World War II), and designed a system of radio control of torpedoes which forms the basis for the modern radio guided missile.

As the following documentary history records, the Navy's subsequent enthusiastic drive and encouragement to scientific research gave the initial impetus and support to what has become the vast electronics industry in America, an industry that plays such an important part in our military and civilian lives.

When the Marconi interests refused an outright sale of radio equipment to the U.S. Navy, Rear Adm. Henry B. Manney, Chief of the Bureau of Equipment, steadfastly refused to accept a system which would have been inadequate for our needs. He insisted upon providing the Navy with a communication system, wholly under its control, which could be expanded in response to requirements, and one which would not stifle our inventive genius.

In the following years the Navy paced the way to United States world leadership in electronics. The United States Navy's first radios, purchased in Europe before American manufacturers entered the field, were limited to ranges under a hundred miles, and covered such wide bands that carrying on two communications simultaneously was an impossibility. An urgent need for more sensitive and sharply tuned sets led naval engineers in the World War I period to champion vacuum tube research and development by domestic producers. Thus stimulated by naval backing, America's inventive genius turned out a reliable vacuum tube.

Originally vacuum tubes had a life expectancy of some 70 hours and cost fifty dollars each, limitations which made their widespread use economically unfeasible. However, shortly after World War I the Navy solicited bids on a 5000 hour tube costing no more than five dollars. The successful bidder met these revolutionary specifications, and in so doing the Navy had sired a major contribution to the wildfire growth of commercial radio in this country, and set our electronics industry off to a booming start. Likewise, high voltage transmission line insulators, of a type now in world wide use, are a development growing out of the Navy's demand for high voltage insulators for shipboard and shore station antenna systems.

The Navy took the lead in airborne radio when in 1912 a naval aircraft, the first plane to carry a radio transmitter, communicated with a ground station at distances up to 16 miles. Four years later, the Navy's aircraft radio laboratory was established at Pensacola to concentrate on development of long range airborne radio equipment. By 1919, a naval pilot, using radio alone, was able to locate and fly to a battleship one hundred miles off shore.

The Navy was the first large user to adopt short wave for regular service use, and the first to initiate organized research in high frequency communications. As early as 1925, the Naval Research Laboratory was able to correlate data explaining in detail the phenomena governing high frequency communications. Radar, the electronic wonder which provided our forces with such a tremendous advantage over the Japanese enemy in World War II, is a never-to-be-forgotten offshoot of the Navy's basic interest and research in high frequency.

At international as well as national communication conferences, the Navy has consistently played a leading role. The first chairman and the first technical adviser to the Federal Communications Commission were naval officers. International acceptance and adoption of the radio spectrum channeling system was a result of naval effort.

Many officers and men in the Navy had a hand in this swift progress. Two outstanding names that I might single out were Admirals S. S. Robison and A. J. Hepburn, both of whom shared the distinction of being Commanders-in-Chief, United States Fleet. Admiral Robison prepared a radio manual that through several revisions remained for years the standard naval text on the subject. Admiral Hepburn convinced naval authorities of the great need of research and development by qualified civilian radio engineers.

If one person were to be termed the father of radio in the United States Navy, it would be Rear Admiral Stanford C. Hooper. He was twice Fleet Radio Officer, thrice Head of the Radio Division, Bureau of Ships, and long time Director of Naval Communications. During his first tour as Fleet Radio Officer he helped to develop sound radio doctrine in the Fleet, established communication discipline, and improved reliability to a point where radio was accepted as a primary means of tactical signaling. After World War I, he championed the concept that American businessmen should combat foreign communications monopolies that endangered our national security. Largely through Admiral Hooper's ideas and energetic efforts, American corporations today play a major role in the field of international radio communications.

Admiral Hooper induced all important American patent owners to pool their patents. This was an inspired move which helped make American manufactured equipment the best in the world. To obtain increased power and ruggedness for naval use, he stimulated vacuum tube research and development. The result was the vacuum tube transmitter which has been the heart of modern radio communications. It was Admiral Hooper who, although initially opposed, later fostered the system of high frequency radio communication which proved indispensable in World War II. Thus, through his dedicated efforts, Admiral Hooper made many contributions of far-reaching importance to the effectiveness of the Navy and national security.

Many other individuals and elements of the Navy likewise contributed in important ways to the development of radio in the Navy. For example, the Naval Research Laboratory in Washington, D. C. did notable pioneer work in radio and especially high frequencies. It was during research in the use of higher frequencies that Dr. A. Hoyt Taylor discovered the phenomenon of radar, the electronic wonder that played such an important role in World War II victory.

These few names I have listed represent hundreds of thousands in and outside the Navy who by their dedicated service made possible the enormous strides in the fields of electronics and communications which have won world leadership for America. The electronics worker in the factory, the radio operator of a warship, and the communicators on distant stations do their part in defending America. Their work and their accomplishments are a part of this electronic history.

When the scope and size of naval operations are enlarged, so too are the problems of command and combat coordination. A World War II Fast Carrier Task Force was deployed over *miles* of ocean, whereas the modern Attack Carrier Task Force of the Atomic Age is spread over *thousands of square miles* with a commensurate increase in the complexity of tactical communications. Naval communications must of necessity keep abreast or ahead of the increased requirements generated by technological developments in ships, aircraft and weapons. The Navy's exacting demand for ever more versatility, ruggedness, reliability, and long operating life which must be built into its electronic systems have constantly stimulated invention and improved design, and will continue to set high standards for the industry.

It is a giant step from the spark-gap transmitter of a half century ago to the transistorized multiplex of today which can simultaneously transmit one hundred words a minute on each of four channels. The intricate electronic complexes which look into the sky, under the sea, and direct our guns, missiles, and aircraft are a far cry from the eyes of a sailor lookout. Yet we merely stand on the threshold of a new and exciting science.

Electronics has had a great past under the leadership of the United States Navy. This complex electronics science will have an even greater future in the Navy of tomorrow. The guided missile ships, space satellite radio recorders, and radio astronomy, indicate the course of events to come. In these events, the Navy will continue to play a vital role.

C. W. Nimitz,
Fleet Admiral, USN

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PART I

The Decade of Development

CHAPTER I

Historic Modes of Naval Communications

ANCIENT AND MEDIEVAL TYPES

Since the time man became gregarious he has sought means of instantaneous long-distance communication with his friends in order that they might succor him when in difficulty or join him in rejoicing in his glories. Before he discovered his ability to control fire such requirements were met by the use of messengers when the distances were greater than sounds would cover. With fire he was able to increase the distance by the transmission of a limited amount of intelligence using signals prearranged with those allied with him.

Early Greek, Persian, and Jewish history records numerous instances when signal fires were used and it must be assumed that these were productive of the most spectacular results. Homer's "Iliad" tells of the chain of beacons, prearranged by the gullible Agamemnon and the beguiling Clytemnestra, whereby he foretold his return to Mycenae after his successful 10 years' seige of Troy, about 1200 B.C., thus giving her and Aegisthus time to arrange his assassination.

One of the first recorded naval usages of fire signals was in the same seige of Troy, when Agamemnon used the flare of a flame from his vessel to signal the beginning of his successful invasion. Herodotus wrote that, during the invasion by Xerxes, three Greek picket vessels off Magnesia sighted the van of the Persian Fleet and warned the Greek Fleet at Artemisium by signal fires. Thucydides records two uses of beacon fires; the first, in the year 427 B.C., when a Spartan fleet of 53 vessels was signaled that 60 Athenian triremes were headed up the coast to attack them; the second, in 411 B.C., when Sestos was warned that 73 Spartan vessels, which had eluded the Athenian fleet at Lebos, were headed for that city.

The Bible records early Jewish use of fire for signaling in Jeremiah 6:1:

> O ye Children of Benjamin, gather yourselves to flee out of the midst of Jerusalem, and blow the trumpet in Tekoa, and set up a sign of fire in Beth-haccerem: for evil appeareth out of the north, and great destruction.

Plutarch, in describing the conditions which existed in the Mediterranean before Pompey's campaign against the pirates, noted that the latter were well equipped and familiar with the use of beacon towers.

The use of artificial light as a means of warning, or calling to arms, has continued throughout the years and down to the present time. In describing the approach of the Spanish Armada toward the south coast of England, Macaulay wrote:

> From Eddystone to Berwick bound, from Lynn to Milford Bay,
> That time of slumber was as bright and busy as the day.
> For swift to east and swift to west the ghastly war-flame spread.
> High on St. Michael's mount it shone, it shone on Beachy Head.
> Far on the deep the Spaniard saw, along each southern shire,
> Cape beyond cape, in endless range, those twinkling points of fire.

Still later, at the beginning of our own American Revolution, signal lights were used on the occasion immortalized by Longfellow's "Paul Revere's Ride":

> He said to his friend, "If the British march
> By land or sea from the town tonight

Hang a lantern aloft in the belfry arch
Of the North Church tower as a signal light,
One if by land, and two if by sea;
And I on the opposite shore will be,
Ready to ride and spread the alarm
Through every Middlesex village and farm
For the country folk to be up and to arm."

This primitive and limited mode of communication did not go unimproved. It was unreliable during daylight and its range was controlled by terrain. The advent of fire was followed by man's acquisition of the knowledge of working and burnishing metals and manufacturing crude implements of war, both offensive and defensive. He was quick to note that the polished surfaces of shields glinted in the sunlight and that this was visible for miles. Herodotus relates that, in 480 B.C., a signal was transmitted from Athens to Marathon by means of a burnished shield. However, the Persians, well aware of the limitations of the beacon by night and the reflection of the sun by day, continued the use of a well-trained courier system, for the same writer also noted;

The Persian messengers travel with a velocity which nothing human can equal . . . . . Neither snow nor rain, nor heat nor darkness are permitted to obstruct their speed.[1]

Agrippa, in a paper published in Antwerp in the 16th century, claimed that Pythagoras, the Greek philosopher of Samos, was aware of the use of the sun's reflection from polished metal for signaling purposes. The lighthouse at Alexandria, Egypt, is purported to have had a reflecting mirror atop it as early as 300 B.C.[2] Emperor Tiberius ruled Rome from the island of Capri for 10 years, around 37 A.D., transmitting his orders by means of the heliograph.[3] This indicates that the Romans, at this time, used some form of telegraphic code in the transmission of information. In Algeria, the Moors were using a device similar to the heliograph in the 11th century.[4]

In the ever-continuing struggle for naval supremacy man increased the size and number of his ships and sailed them together for both defensive and offensive purposes. The manipulation of sails, the location of national ensigns or other flags or shapes upon the masts, lanterns and gunfire sufficed for signaling in the earlier loose formations. As time went on, tactics changed and tighter formations became necessary to provide mutual protection. The complexity of maneuvers increased and required more signals.

The invention of the telescope, by Hans Lippershey in 1608, and of the binoculaı, by Gallileo the following year, increased the range of man's vision, especially at sea. Some 40 years later the Duke of York, later James II, introduced a flag signaling system in the British Navy. This was a simple system, contained in the "Fighting Instructions," consisting of less than 25 signals which could be made by the display of any one of 5 flags from any one of 5 vantage points; the foretruck, maintruck, mizzentruck, spanker gaff, or after flagstaff.[5]

SIGNALING DURING THE AMERICAN REVOLUTION

Although, at the outbreak of the American Revolution, the English Navy was the best and most efficient in the world, there had been little improvement in its tactical signaling during the 18th century. Lord Anson, while First Lord of the Admiralty, had authorized maneuvers in addition to those contained in the "Fighting Instructions." However, there being "no means of signaling them . . . confusion became the order of the day." [6] Adm. Lord Richard

[1] Herodotus, "Arania," book VIII, ch. 98.

[2] Alvin L. Harlow, "Old Wires and New Waves" (D. Appleton-Century Co., 1936.), p. 10.

[3] Ibid., p. 10. In this case the heliograph refers to an apparatus for telegraphing by means of the sun's rays thrown from a mirror or polished metal surface.

[4] Ibid., p. 10.

[5] Ibid., p. 11.

[6] Ralph Earle, "The Origin of Our Signal Book," U.S. Naval Institute Proceedings, vol. 38, September 1912, pp. 1037–1038.

Howe, while engaged in leading the British against the colonists, became sufficiently provoked and aroused to attempt a revision of the signal system of the "Fighting Instructions." In his proposed revision a page was devoted to the use of each flag and its tactical meaning when hoisted in any of various specified positions. This revision was not accepted and no change was made in the basic system.[7]

Our Revolutionary Fleet was made up of privateers, State navies, and the Continental Navy. There was little difference between the first two groups relative to their emphasis on signaling. Usually there were simple instructions covering recognition signals and a few maneuvering signals for ships in company, issued by commanders for vessels under their command. Typical of these is an instruction excerpted from an operation order of that time:

> Should anyone of the fleet discover a strange sail, he will hoist a lantern in the best place to be seen and fire a gun, if he has one.[8]

Although somewhat in variance with existent naval strategy, vessels of these units generally fought singly and little needed a publication such as the "Fighting Instructions" of the British.

On 5 January 1776, the Naval Committee of the Continental Congress issued its "Orders and Directions for the Commander in Chief of the Fleet of the United Colonies." These were possibly the first naval instructions issued by the Continental Congress. In these orders, Commodore Ezek Hopkins, our first Naval Commander in Chief, was instructed:

> to devise or adopt and give out to the Commanding Officer of every Ship, such Signals and other marks and distinctions as may be necessary for their directions.[9]

The orders issued by Commodore Hopkins and "given to the several Captains in the fleet on sailing from the Capes of Delaware, February 17, 1776," [10] consisted of a few tactical maneuvers and battle orders which were signaled by the manipulation of sails or the position from which pennants, the ensign, or other national flags were flown.[11] Even in comparison to the inadequate signal systems used by the English and other European navies, these must be regarded as elementary.

In January 1777, Robert Morris, a member of the Marine Committee of the Continental Congress, directed Capt. Nicholas Biddle to send him—

> Signals by which you may be known, in case we should send out any of our small cruisers to look for you, also to deliver to the other frigates that may go from hence to Rhode Island, . . .[12]

Later in April of the same year, the committee ordered the commander of the squadron sent to intercept the British Jamaica Fleet—

> Fix signals for discovering the enemy, their numbers force and number of the convoy, how they bear, . . .[13]

In April 1778, the Marine Committee promulgated general instructions, including the following, which expressed its policy in the matter of new signals:

> As the New Signals for the Navy have been sent to the Navy Board of the Eastern Department and have been given to several Commanders we think it would be improper to alter them at this time, however as it may be necessary hereafter to change the Signals, we would be glad if you would compose a set.[14]

While it appears that little improvement took place during the conflict, the subject

[7] Ibid., p. 1039.

[8] Gilbert Totten McMaster, "Signal Codes Used by Our Revolutionary Commanders for the Convoy of Merchantmen," U.S. Naval Institute Proceedings, vol. 38, Sept. 1912.

[9] "The Correspondence of Ezek Hopkins, Commander-in-Chief of the United States Navy," edited and annotated by Alverda S. Beck (Rhode Island Historical Society, Providence, 1933), p. 7.

[10] George Henry Preble, "History of the Flag of the United States of America" (A. Williams & Co., Boston 1882.), p. 232.

[11] "The Correspondence of Ezek Hopkins," op. cit., p. 17.

[12] "Out-Letters of the Continental Marine Committee and Board of Admiralty, 1776–1780," vol. I, p. 65, edited by C. O. Paullin, New York.

[13] Ibid., p. 119.

[14] Ibid., pp. 223–224.

of signaling was discussed in at least 26 of the "Out-Letters" of the Marine Committee and Board of Admiralty between January 1777 and October 1780.[15]

It remained for Capt. Richard Kempenfelt, Royal Navy, to whom Lord Howe turned over his signal book upon retirement, to carry on the fight and lay the foundation for a future visual signal system ultimately to be adopted by all navies. A serious student of naval tactics, he determined that the "whole system of the 'Fighting Instructions' should be abolished because of their utter inefficiency." [16] He developed a system for the Royal Navy, based upon that of the French tactician, Mahe' de la Bourdonnai, wherein numbers were allotted to flags. Kempenfelt faced a long struggle against custom, tradition, and the inherent inertia of his senior officers, but he seized every opportunity to use his system in squadron drills. His superior in command, Admiral Geary, once chided him:

> Now my dear Kempy, do for God's sake, do my dear Kempy, oblige me by throwing your signals overboard and make that which we understand. "Bring the enemy to close order action." [17]

Finally, in 1798, it was officially accepted. The system of allotting numbers to flags revolutionized tactics since the number of signals could be increased to whatever might be reasonably necessary. Kempenfelt's system contained a combination of 246 signals.[18]

EARLY NAVY SIGNALING

In 1797, Capt. Thomas Truxtun, USN, issued the first American naval signal book using the numerary system. This system encompassed 10 numeral pennants, made of combinations of red, white, blue, and yellow bunting, with flags for repeaters.[19] It contained approximately 290 signals. During fog they were indicated by gun and musket fire and at night by lanterns and gunfire. Since these directions were indefinite, he stated:

> They must have been agreed on beforehand; for example, each light to tell for one, and each gun firing for ten more or less, as may be agreed upon; so if you want to signal 27, you fire two guns, after having put seven lights in the most conspicuous place in the ship . . . .[20]

Truxtun's advice, as contained in his "Signal Book," should be interesting to naval officers of today:

> For the advantage of dispatch, and the more convenient distribution of orders, the officers summoned by signal are to attend on board the Commodore, provided with an orderly book, wherein they are to minute down the receipt of all public letters and orders then to be delivered, to enter all verbal directions given, and all written instructions to be copied from the daybook of the ship in which the Commodore is embarked, and to sign their names in evidence of the receipt of such orders and directions when so required.
>
> The establishment and organization of a navy, in an infant country, is much more difficult than imgined by people in general—for the officers in the first place are, and from the nature of their previous life, cannot be otherwise than uninformed men, who mostly have an aversion to reading and studious application, and notwithstanding there are authors to be found on the various subjects of naval science, yet they are so lame that there are many particulars essential in an extreme, that will be found impracticable to get a knowledge of from such authors or the commanders of any old maritime country; for it is but natural that nations frequently in the habit of quarrelling and going to war should be tenacious of communicating the improvements they make, lest their enemies by gaining a knowledge thereof, should turn them to their own advantage; and it is equally natural, that officers who look forward to become conspicuous in their profession, should also be very tenacious of communicating what their genius or industry had invented, except to their own nation,

[15] Ibid., vols., I, II.

[16] McMaster, op. cit., p. 1039.

[17] "Signals and Instructions" (1776–94), edited by Julian S. Corbett, printed for the Navy Records Society, London 1908, p. 40.

[18] Earle, op. cit., p. 1040.

[19] When the same numeral flag was required in a signal more than once, a repeater pennant was used. Thus, the display for signal 111 would be one-pennant, first-repeater, second-repeater.

[20] Thomas Truxtun, "Instructions, Signals and Explanations Offered for the United States Fleet," (printed by John Hayes, Baltimore, Md., 1797), p. 29.

particularly as it is by various maneuvers, new and old, that a competent knowledge of tactics and seamanship is acquired, and that advantage are frequently gained at sea by very inferior forces over superior ones is evident. As for instance, Admiral Cornwallis's escape in 1795, with a few ships from a French fleet, as also Sir John Jervis's victory over a Spanish fleet of double his force, in February last; and again, the numerous advantages gained by Sir Sidney Smith, Sir B. Warren, Sir Edward Pellew, and many others of the British Navy, during the present European war, where their force was very inferior to that of their enemy, but the abilities of the commander of a fleet in other respects ever so great, and that of the Captains ever so intrepid, without he contrives simple and efficient signals, the success of a sea-battle even with superior force must and will be always uncertain: hence it is, that the importance of this subject must be very obvious to the war officers of our country, and to every reflecting mind, and the more so, as the outlines of signals and great naval evolutions can only be borrowed, from authors now extant, and but few of the number and sort that are necessary to form a complete code for the government of the Navy of the United States of America are attainable.[21]

Official recognition was given Truxtun's "Signal Book" by the Secretary of War, James McHenry, but unfortunately its use was soon discontinued because of discrepancies found between the original manuscript and the printed copies.[22]

After the withdrawal of the "Truxtun Signal Book," one compiled by Commodore John Barry, USN, and Capt. James Barron, USN, was issued in 1802, under a directive of Secretary of the Navy Benjamin Stoddart. This was commonly known as the "Barron Signal Book" and was used until it was compromised, sometime during the War of 1812. It was better organized than Truxtun's but was not basically different.[23] During this period numerous special signal books were used for specific missions.

Following the War of 1812, a revision of the "Barron Signal Book" was made by Commodore William Bainbridge, USN, and approved for use by the Secretary of the Navy. This revision substituted flags for pennants and added shapes. A private number system, which was merely a simple system of encipherment, was added. From time to time new editions were promulgated, containing additional signals required by new tactical maneuvers and battle orders, with the format remaining unchanged.

Until 1842, the senior member of the Navy Board was responsible for the signal book and the private cipher. With the establishment of the Bureau system in that year the responsibility was assigned to the Bureau of Construction, Equipment, and Repair.[24] In 1853 the responsibility for the private cipher was transferred to the Bureau of Ordnance and Hydrography.[25]

Meanwhile, with the advent of the telegraph, which came into extensive use between the Navy Department and commanders of squadrons based in ports where this facility was available, the Navy, in February 1847, adopted the Rogers and Black "Semaphore Dictionary" but retained the signal book for tactical purposes.[26]

Illustrative of the communication difficulties existing in 1846, when the Mexican War began, Commodore Sloat, commanding the U.S. Pacific Squadron off Mazatlan, was unable to obtain news of its outbreak, since such news could only come through Mexico. Sloat was concerned that the British, who had also concentrated a sizable force at Mazatlan, would endeavor to occupy California under the pretext of protecting their financial investments there. Fortunately, one of his officers had received orders transferring him to other duty and, just before the outbreak, was traveling through Mexico on his way to the United States. Upon learning of the beginning of hostilities, he managed to get the informa-

[21] Truxtun, op. cit., pp. 35–36.

[22] "History of Naval Communications 1776–1919" (unpublished manuscript), p. 26.

[23] Circular letter, dated 21 Sept. 1861, Bureau of Ordnance and Hydrography, National Archives, Washington, D.C.

[24] Circular letter, dated 23 Jan. 1862, Bureau of Ordnance, National Archives, Washington, D.C.

[25] Records, dated 16 Nov. 1863, Bureau of Ordnance, National Archives, Washington, D.C.

[26] B. Franklin Greene, "Chronosemic Signals" (Washington, D.C.).

tion to Sloat, who moved in and seized California for the United States before the British commander received information that a state of war existed.[27]

In 1841, John Ericson, inventor of the screw propeller, was induced to come to the United States, where he designed the screw propelled U.S.S. *Princeton.* Following this, the transition from sail to steam was rapid. This caused many changes in tactics and the 1813 signal book, despite numerous revisions, soon became totally unusable.

In 1847 the Rogers and Black "Semaphoric Dictionary," and its included system of flag signals, was adopted additionally for tactical signals and promulgated to the service by the Secretary of the Navy.[28]

In 1856 Comdr. J. B. Marchand, USN, in a letter to the Secretary of the Navy, discussed the shortcomings of a proposed revision of the signal book. He recommended the following: the altering of the numerical designation of the flags; that night signals be made by a series of lanterns which corresponded numerically with the day signals; explanations of the five orders of fleet sailing; diagrammatic explanations of maneuvers; the introduction of the steam trumpet for use in fogs, in lieu of the whistle; and the elimination of obsolete signals.[29] The contents of the letter were sufficiently convincing to cause the Secretary to appoint a board, consisting of Marchand, Capts. Charles S. McCuley and E. A. F. Lavalette and Comdr. Charles Sterdman, USN, to compile a new signal book. The board completed this in 1858, taking cognizance of requirements resulting from changes which had occurred during the previous 45 years. The responsibility for the new signal book and the signal cipher was assigned the Bureau of Ordnance and Hydrography, which already had the responsibility for the private cipher.[30]

The Rogers and Black "Semaphore Dictionary," adopted in 1847, was continued in use. It included a signaling system based upon the use of colored pyrotechnics. At this time, Gunner Costen improved the brilliancy of pyrotechnics and evolved a percussion ignition system which facilitated their use.[31] In 1860 Roger's Commercial "Code of Signals" was added to the codes and ciphers in use.[32]

SIGNALING DURING THE CIVIL WAR

When officers from the Southern States resigned their commissions at the beginning of the Civil War, they took with them knowledge, and possibly copies, of all naval codes and ciphers. A new signal book was hastily compiled and issued in 1861. This action is difficult to understand in light of our present knowledge of cryptography. It would seem that a simple additive cipher, varying daily if necessary, for use with existing numeral codes, would have sufficed for tactical signaling, and that a transposition cipher of relative simplicity would have made telegraphic dispatches secure.

The sudden loss of officers, many of whom had been in responsible billets, resulted in the Navy Department becoming dominated by confusion. The failure to delegate the responsibility for code and ciphers to a qualified individual resulted in several actions which are difficult to understand. A circular, dated 12 September 1861, addressed to "the Regulars," contained a directive prohibiting the issue of the "Private Signal Book" to vessels com-

[27] Files, dated 7 July 1863, Bureau of Navigation, National Archives, Washington, D.C.

[28] Secretary of the Navy letter of promulgation, dated 16 Feb. 1847.

[29] "Official Records of the Union and Confederate Navies in the War of Rebellion, 1906," series I, vol. 1, p. 146, Washington, D.C.

[30] Letters, dated 21 Sept. 1858, Bureau of Ordnance and Hydrography, National Archives, Washington, D.C.

[31] "History of Naval Communications 1776—1919," op. cit., p. 26.

[32] Letters, dated 27 Feb. 1960, Bureau of Ordnance and Hydrography, Naval Archives, Washington, D.C.

manded by volunteers.[33] A few days later, the Secretary of the Navy, Gideon Welles, directed that the Commercial Code, with an appendix of modifications "is to be used solely in communicating between the Regular and Volunteer Service." [34]

The new signal book, hastily prepared in 1861, was so unsatisfactory that many local changes were made to it. This soon resulted in so much confusion that the Bureau was forced to issue orders forbidding unauthorized changes.[35]

The responsibility for signals was transferred to the Bureau of Navigation in 1862 and that Bureau immediately installed the Myer's (wigwag) system of signaling and required all young officers to become proficient in its use.[36]

On 29 May 1862, the Secretary of the Navy appointed another commission to study the subjects of signals and signaling and to make recommendations for improvement. This was composed of Capt. A. W. Davis, USN, Chief of the Bureau of Navigation; Capt. A. W. Boche, USCS, and Joseph Henry, noted American scientist and first Director of the Smithsonian Institution. Excerpts from the commission's recommendations are quoted:

> I. The Commission recommends the printing of the proposed new edition of the Telegraphic Dictionary.
>
> II. It recommends the printing of a new edition of the Naval Signal Book with the reconstruction of the Naval Signal System, upon the basis proposed by the Bureau of Navigation. This improvement consists in giving to the flag and light symbols for day and night service, respectively, a unity and symmetry, which in the opinion of the Commission, would secure to these methods greater facility and efficiency in ordinary use, and, at the same time, furnish a means of confidential communication, even in the presence of an enemy in possession of the Signal Book. This is not a radical change of the present sets of Signal Flags and Lights. All the fundamental principles of the present system of day and night signals are to be retained.
>
> III. The method, of Chronosemic Signals,[37] of Mr. Greene, appears only to day and night use, in an open sky, but a matter of importance to a state of fog. The system is simple, precise, and comprehensive; while it appears to be susceptible of facility and rapidity of use.
>
> These qualities, in addition to its apparent universality of application to all circumstances, either of weather or of situation, render Mr. Greene's method in the opinion of the Commission, worthy of a special consideration. They therefore recommend that this system be substituted for the present system of Flag Signals, and that such explanations of it be added that it may be used, if the occasion should acquire, in place of the usual system, for day and night service; a use for which it would be equally adapted, owing to its perfectly general nature.
>
> IV. The method of Secret Signals, proposed by the Bureau was partially explained to the Commission; sufficiently so, to indicate the general principles upon which the method is based. The Commission is of the opinion that a method which promises the results thus set forth, would be highly useful to the Naval Service, and should be immediately introduced.[38]

Things moved slowly, with confusion continuing to exist, and in 1864, near the end of the war, Admiral Farragut wrote the Chief of the Bureau of Navigation:

> You will have to do something to simplify the signals, they have been changed so frequently that we scarcely learn the flags before they are altered. I really beg that you will give this subject your attention for I look for some disaster daily.[39]

A DECADE OF STAGNATION

Following the Civil War, lethargy was dominant, insofar as improvement in sig-

[33] Records, dated 12 Sept. 1861, Bureau of Ordnance and Hydrography, National Archives, Washington, D.C.

[34] Circular letter, dated 21 Sept. 1861, Bureau of Ordnance and Hydrography, National Archives, Washington, D.C.

[35] Circular letter, dated 23 Jan. 1862, Bureau of Ordnance and Hydrography, National Archives, Washington, D.C.

[36] Records, dated 16 Nov. 1863, Bureau of Ordnance and Hydrography, National Archives, Washington, D.C.

[37] Greene, op. cit., p. 7, "Chronosemic Signals" (*chronos*, time, and *sema*, a sign: thus, time sign) are based upon use of a series of sound signals combined with time intervals readily applicable to a code and employable during fog or any condition of weather, day or night.

[38] Files, dated 7 July 1863, Bureau of Navigation, National Archives, Washington, D.C.

[39] "Official Records of the Union and Confederate Navies in the War of Rebellion," op. cit., series I, vol. I, p. 146.

naling methods were concerned, and little of consequence occurred for several years. Finally, in 1869, effort was again made to correct conditions. A new signal book was issued and the flags were again changed.[40] Commodore S. P. Lee, USN, was made the head of a newly established Navy Signal Office. He was directed to confer with the Chief Signal Officer of the Army—

> for the proper teaching and organization of a signal corps in the Navy, similar to that now so successfully employed in the Army.[41]

Lee served in this capacity until 1870, when he was relieved by Commodore John J. Almy, USN, who was, in turn, relieved by Commodore Foxhall A. Parker, USN, in 1874. Much was done toward the furtherance of training of signalmen during this period, but no serious consideration was ever given to the establishment of a corps similar to that of the Army.

In 1869 a telegraphic office was established in the Naval Observatory with lines connecting it to the Navy Department, the Washington Fire Alarm Telegraphic Office, and Western Union, for the purpose of communicating exact time.[42] This was the forerunner of the Navy's present worldwide time broadcasts.

About 1872 the Navy Signal Office issued an American edition of the International Code. This proved of great value in facilitating communications between the Navy and our Merchant Marine.[43]

Despite Bureau requirements and quarterly submissions of reports stating the amount of time devoted to signal exercises and the degree of efficiency attained, interest in signaling appears to have waned. In 1882, the Chief Signal Officer, Capt. P. C. Johnson, USN, reported, "the practice of signaling has been neglected."[44] This condition continued, with few corrective measures being taken, until the abolishment, in 1890, of the Office of the Chief Signal Officer.

DEVELOPMENT OF ELECTRICAL COMMUNICATIONS IN THE NAVY

Experimentation with electric lights for naval signaling was commenced in 1875. Two years later Lieutenant W. N. Wood, USN, perfected an electric system for visually transmitting the English Morse telegraphic code, which had been adopted for use the previous year. This electric system was installed in U.S. naval vessels the following year.[45] In 1891 the French Ardois system of light signaling was introduced in some squadrons.[46] This was supplemented, in 1897, by the Telephotos system, similar to the Ardois but having an improved keyboard.[47] Electrical equipment, which had been the assigned responsibility of the Bureau of Navigation, had become so complicated that that Bureau did not have qualified technical personnel capable of dealing with its intricacies. Consequently, in 1897 it was made the responsibility of the Bureau of Equipment. Since signaling equipment had, to a large extent become electrical, all signaling apparatus was included in this transfer.[48]

By 1890 commercial telegraphic or cable facilities were available in practically every port frequented by the Navy. These facilities provided rapid communication between the Navy Department and the com-

[40] "General Orders and Circulars, Navy Department, 1863–69," p. 365.

[41] Annual Report of the Secretary of Navy, 1869, p. 52.

[42] Ibid., p. 56.

[43] Annual Report of the Secretary of Navy, 1874, p. 62.

[44] Annual Report of the Secretary of Navy, 1882.

[45] Annual Report of the Secretary of Navy, 1878, p. 157.

[46] Annual Report of the Secretary of Navy, 1892, p. 131.

[47] Annual Report of the Secretary of Navy, 1897, p. 200. The Ardois system was used for night signaling at sea with Morse code, in which a series of double lamps, arranged vertically, and showing alternate red and white lights were operated from a key-board.

[48] Annual Report of the Secretary of Navy, 1890, p. 110.

manders of squadrons, when in port. This permitted the Navy Department to keep its commanders advised of the political situation, but lessened the amount of discretion allowed them. Many a grizzled old seadog was wont to complain, "The Navy isn't what it used to be." A senior officer, while on the China station, is purported to have commented, "Now we have become mere messenger boys at the end of the cable."

The first known naval use of any light projector, which could be regarded a signal searchlight, was on board a Union warship blockading a Confederate-held port during the Civil War.[49] While this device was especially well adapted for night signaling, it is also usable, to a limited extent, during daylight, depending upon the location and brilliance of the sun.

Later the arc-signal searchlight, with its quick-closing, venetian-blind shutter, and the portable 5-pound Aldis signal light were designed and developed for signaling purposes.[50] Although not a competitor of the heliograph in range, a 12-inch searchlight, under favorable conditions, may be seen as far as 9 miles by day and over 16 miles at night. It has the added advantage over this ancient predecessor of not being dependent upon the sun.[51]

WINGED MESSENGERS

In the latter years of the century a version of the "winged messenger" system was added. In this case the "winged messengers" were homing pigeons, capable of flying considerable distances over water. Prof. Francis Marion, U.S. Naval Academy, was sent to Belgium to obtain information on the care and training of these birds. Upon his return he published a pamphlet of instructions on the subject.[52] Cotes were established at several shore stations and training was conducted under the direction of well-qualified persons. Only limited success was obtained because the "messengers" were subjected to too many obstacles. The advent of radio, at this time, tended to dampen interest in the pigeons. A board appointed in April 1901, to consider the advisability of adopting a radio system, recommended the immediate abolishment of the homing pigeon service. Although there was considerable retrenchment in the program, as a result of this recommendation, it did not mean the end of this service in the Navy.[53] As late as 1942, orders were issued to expand the flock of several hundred birds for use between dirigibles and their naval air stations.[54]

NAVAL COMMUNICATIONS DURING THE WAR WITH SPAIN

While driving back from the Capitol to the White House after the inauguration, 4 March 1897, Cleveland remarked to McKinley, "I am deeply sorry, Mr. President, to pass on to you a war with Spain. It will come within 2 years. Nothing can stop it." [55]

McKinley shared Cleveland's pessimism and, from the beginning of his administration, took action to strengthen our coastal defenses. On 18 October 1897, the Secretary of the Navy appointed a board consisting of Comdr. John Schouler, USN, senior member; and Lt. C. H. Harlow, USN, Flag Lieutenant North Atlantic Squadron;

[49] Ernest Boghosian, "History of Naval Searchlights," Journal of the American Society of Naval Engineers, vol. 68, No. 3, August 1956, p. 503.

[50] "Searchlights and Signal Lights," Navy Department, Bureau of Steam Engineering, November 1918, Washington, D.C., p. 115.

[51] J. Heinz, "Electric Searchlights at Sea," Proceedings of the U.S. Naval Institute, vol. 20, April 1894, p. 781.

[52] Francis Marion, "Report on the Military and Private Homing Pigeon System of Belgium," Records, Bureau of Equipment, National Archives, Washington, D.C.

[53] Report of the Secretary of the Navy, 1902.

[54] Press and radio release, Navy Department, 28 Feb. 1942.

[55] David Saville Muzzey, "A History of Our Country" (Ginn & Co., Boston, Mass., 1943, p. 533.

Lt. J. H. Gibbons, USN, Naval Militia Bureau, Navy Department; and Lt. F. B. Anderson, Signal Officer Naval Militia of New York, for the purpose of considering the advisability of establishing coast signal stations as a part of the scheme of naval defense. Schouler submitted their recommendations on 27 October and they were subsequently approved by the Secretary, but were not put into effect immediately.[56]

When, by 9 April 1898, our relations with the Spanish Government had deteriorated to the point where war seemed inevitable, Capt. C. F. Goodrich, USN, was directed to organize the coast signal system in accordance with the approved recommendations. Three days later he wrote the commanding officers of naval militia organizations, providing them with complete details as to stations to be established, station personnel, equipment allowances, and details of organization.[57]

Congress, on 19 April, passed resolutions recognizing the independence of Cuba and authorizing the President to employ the military and naval forces of the United States in the support of a demand for the immediate withdrawal of Spain from that island. The Navy Department, on 22 April, directed Capt. Goodrich to establish the stations of the coast signal system. Within 2 weeks the entire system was placed in operation. The organization divided the Atlantic and gulf coasts into seven districts, each under a commanding officer, reporting directly to Captain Goodrich at his headquarters in the U.S.S. *New Hampshire,* armory of the 1st Naval Battalion of New York. The system consisted of 230 stations, provided by the Lighthouse Board, the Lifesaving Service, the Weather Bureau, or the Navy. Thirty-six of these were primary stations, manned by naval militiamen. All stations were connected to telegraph or telephone systems and were equipped with the International Code of Signals, signal flags, shapes, torches, and an improved Ardois system of red and white lights. All signalmen were capable of signaling by wigwag and were equipped with good binoculars and powerful telescopes.[58]

During the short period of the war, the system, while not actually sighting an enemy, since there was none along the coast to sight, gave excellent service in keeping the Navy Department advised of the movements of ships and in affording the various navy yards advance information of the arrival of ships for stores, overhauls, or repairs. Its major contribution was in allaying the usual wartime fears of inhabitants of the coastal regions.[59] Following the war, this system fell into disuse and was eventually disestablished. It has often been referred to as the predecessor of the U.S. naval communications system.

On the other side of the world, events occurred which pinpointed the weakness in depending upon nonnational communication facilities in time of war. Commodore George Dewey, USN, in command of the Asiatic Squadron, was in Hong Kong when he was alerted and given instructions on 25 February 1898. He remained there in order to keep informed of the political situation and to receive further orders. The Navy Department's cable connections with him were via the Atlantic, down through the Mediterranean, the Red Sea, and the Indian Ocean, and on to Hong Kong. The Spanish Government's communication with its commander at Manila was via the necessary portion of the same cable and a British-owned cable between Hong Kong and Manila.

On 24 April, Dewey was directed to proceed against the Spanish Fleet at Manila. His sailing was delayed until the 27th, while he awaited the arrival of the U.S. consul from Manila. On 1 May Dewey arrived off Manila, engaged and defeated the Spanish Fleet. The city was at his

[56] Report of board appointed to consider establishment of coast signal stations, dated 27 Oct. 1897.

[57] F. B. Anderson, "The Coast Signal System," United States Naval Institute Proceedings, vol. 25, Dec. 1899, p. 732.

[58] Ibid., p. 742.

[59] Ibid.

mercy, but he had to wait for troops being transported from San Francisco before beginning land operations.

For the first time in history the political aspect of communications became a problem. The Navy Department considered it advantageous to declare submarine cables neutral and on 25 April directed Admiral Sampson not to interfere with their operation. Although Dewey received no such order, he had not planned to sever the cable between Hong Kong and Manila. In fact, he had not even contemplated the necessity of using dispatch boats between the two cities.[60] After the Battle of Manila Bay, Dewey sent a message to the Spanish commander proposing that both belligerents be permitted to use the cable between Manila and Hong Kong.[61] This proposal was refused. The cable company's Philippine concession stipulated that no messages forbidden by the Spanish Government would be transmitted over it. Since it was only of value to the Spanish defenders the cable was severed, at Dewey's direction, on 5 May. No effort was made to haul its seaward end abroad ship to reestablish communication with Hong Kong. Not being able to use the cable from Manila, Dewey was forced to send a dispatch vessel with the report of his victory to Hong Kong for cable transmission to Washington, where the message arrived on 7 May. Had the cable remained intact there would have been no further fighting after 12 August, for on that date, as U.S. troops were moving in to attack and occupy Manila, the peace protocol was being signed in Washington. Dewey received this information, on 16 August, 4 days after the Spanish surrender.

The severing of the Manila-Hong Kong cable established a precedent. Shortly thereafter, the Navy Department directed the severing of cables landing in Cuba in order to isolate the Spanish commander from his homeland. This was accomplished on 4 June.

As a result of one of the lessons learned during the conflict, the U.S. Government insisted that a proposed cable between the United States and the Philippines land only on soil under U.S. sovereignty. The cable company was completely in agreement, but insisted that the Navy Department lend full assistance and backing in the acquisition of the necessary islands, either by the treaty of peace with Spain or by purchase. In order to provide one of the landings, the U.S.S. *Bennington* was sent to occupy unclaimed Wake Island in the name of the U.S. Government. Additional naval assistance was provided by a hydrographic survey west of Hawaii.

During this war intrafleet communications were satisfactory and little comment was made concerning them. The acute need of some means of rapid communications between the various squadrons and the Navy Department was positively indicated, since there developed a growing tendency to to make naval strategic decisions at Washington instead of in the theater of operations. Communications between the Army and Navy were not satisfactory during the joint operations conducted along the south coast of Cuba.[62] In view of the developing needs, the advent of radio was most timely and the Navy Department became interested in its possibilities immediately upon the conclusion of the conflict.

[60] H. W. Wilson, "The Downfall of Spain" (Sampson, Low, Marston Co., London, 1900), p. 157.

[61] Nathan Sargent, "Admiral Dewey and the Manila Campaign," Naval Records Collection of the Office of Naval Records and Library, 1904, National Archives, Washington, D.C.

[62] Infra, p. 70.

CHAPTER II

Birth of Science of Radio and Development of Usable Components

BASIC REQUIREMENTS

Light, heat and electromagnetic waves all travel with the same velocity but differ in wave length. The sun sets up both light and heat waves in the ether which travel earthward and become perceptible to the senses through the eyes, as light, and through the skin, as heat. Electromagnetic waves are not perceptible to any of the human senses, therefore, their use for the telegraphic transmission of intelligence requires manmade apparatus. In simplest form, this consists of: (1) equipment for generating and radiating these waves into the ether; and, (2) a conductor upon which these waves impinge, connected to a suitable receiving circuit. When the transmitted waves reach the conductor and travel down its length they set up a flow of alternating current within it. The voltage induced is directly proportional to the amplitude of the impinging wave at that point. When this conductor is connected to a receiving circuit capable of translating these voltage changes into aural or visual presentations the receiving equipment is complete.[1]

[1] After science of electronics was applied to radio, a simpler means of accomplishing transmission of both telephonic and telegraphic intelligence was developed. This consists of generations of continuous waves of constant amplitude (carrier). Prior to transmission, the waveform of the carrier is modulated by imposing upon it a second waveform of perceptible frequency and varying amplitude. Reception of intelligence is accomplished by reversing the above process. The carrier wave is eliminated by demodulation, leaving only the lower frequency.

BIRTH OF THE SCIENCE OF RADIO

The beginning, but not the application, of the science of radio must be attributed to the scientific efforts and vision of Michael Faraday and the mathematical genius of James Clerk Maxwell. In devising a primitive dynamo, Faraday demonstrated that an energized conductor transmits lines of force into surrounding space and that these can be harnessed and translated into useable energy. He further envisioned that these lines of force extended to infinity and that they were, in some manner, related to light.[2] Maxwell translated Faraday's ideas and visions into mathematical equations. He proved that electromagnetic waves travel through space, with a speed exactly equal to that of light, in a direction transverse to that in which they are propagated.[3]

UNSUCCESSFUL ENDEAVORS TO COMMUNICATE WITHOUT WIRES

The first recorded effort to devise a system of electromagnetic communications without wires came shortly after Maxwell mathematically outlined and predicted the actions of electromagnetic waves. Dr. Mahlon Loomis, a dentist of Washington, D.C., be-

[2] James Gerald Crowther, "British Scientists of the Nineteenth Century," (K. Paul, Trench, Trubner, London, 1935), pp. 106–122.

[3] Ellison Hawks, "Pioneers of Wireless" (Methuen and Co., London, 1927.), p. 177.

came interested in the possibility of using electric waves for communication between two points. He conducted experiments in the Blue Ridge Mountains, in the vicinity of Washington, and, by 1872, had obtained some measure of success. He applied for a United States patent, stating in the specifications which form a part of the Letters Patent:

> . . . What I claim as my invention or discovery, and desire to secure by Letters Patent, is............................
>
> The utilization of natural electricity from elevated points by connecting the opposite polarity of the celestial and terrestrial bodies of electricity at different points by suitable conductors, and, for telegraphic purposes, relying upon the disturbance produced in the two electro-opposite bodies (of the earth and atmosphere) by an interruption of the continuity of one of the conductors from the electrical body being indicated upon its opposite or corresponding terminus, and thus producing a circuit or communication between the two without an artificial battery or the further use of wires or cables to connect the co-operating stations.[4]

Loomis was granted U.S. Patent No. 129,971, dated 30 July 1872, for "Improvement in Telegraphing," following which the matter was not pursued. U.S. patents were granted, for ideas similar to those of Loomis, to Professor Amos Dolbear in 1882, and to Phelps and Edison in 1885. In 1886 Dolbear was granted a U.S. patent on an induction system of wireless telegraphy. This patent was later claimed as the basis for establishing one of the first radio companies in the United States.

HERTZ'S CONTRIBUTIONS TO THE SCIENCE OF RADIO

At the time Dolbear, Edison, and Phelps were endeavoring to develop communication systems not connected by wire, Henrich Hertz was experimentally investigating the nature of electromagnetic waves. In conducting his experiments he developed an oscillator for generating high-frequency electromagnetic waves.[5] Essentially, this oscillator was the first radio transmitter.

A usable radio telegraph system still required a receiver capable of both detection and translation. Hertz developed a detector by adding metal balls to the ends of a wire about 7 feet long and then bending it into a ring with a short gap between the two balls. By increasing the area of the balls through the addition of small plates soldered to them, he was able to bring the ring into resonance with the oscillator. With the equipment in this "electrical condition" he was able to detect his oscillator transmissions, at distances up to 25 feet, by observing the spark across the gap of the detector.[6]

By further experimentation, Hertz was able to verify Maxwell's mathematical deductions. Additionally, he proved that electromagnetic waves obeyed the laws previously evolved concerning the action of light waves, and that they could be focused in beams of various widths by reflection from appropriately shaped metal surfaces.

It may well be that Hertz saw the possibility of his discoveries being developed into a mode of communication, or it may be that the was so deeply engrossed in the scientific aspects of the problem that he overlooked its practical side. His early death, 1894, deprived the world of the benefits of further experiments by him.

EARLY U.S. NAVY INTEREST IN THE DEVELOPMENT OF COMMUNICATIONS WITHOUT WIRE

During this same period, a young officer of the U.S. Navy, Lieut. Bradley A. Fiske, had become interested in the possibilities offered by communications without wires.

[4] E. H. Loftin, "Marconi–Father of Radio?", Radio-Craft, Jan. 1939, (Radcraft Publications Inc., Springfield, Mass.), p. 426.

[5] W. Rupert Maclaurin, "Invention and Innovation in the Radio Industry," (the Macmillan Company, New York, 1949.), p. 16.

[6] W. H. Eccles, "Wireless" (Oxford University Press, Home University Library No. 160, London, 1933.), pp. 28–29.

He was convinced that the Navy was in need of some form of signaling that could be used during fog and darkness as well as by bright daylight. After studying all available scientific reports on the subject, he turned to the theories of Professor Dolbear. He wrote Dolbear, on 31 August 1888, asking him pertinent questions concerning the details of his system. At this time he was serving in the U.S.S. *Atlanta,* commanded by Captain Francis M. Bunce, USN, whom he regarded as,

> One of the finest men I have ever known.

and who

> Helped me as much as he could in getting the Navy Department to let me have a little money now and then with which to get the electrical equipment made.[7]

His first experiment is best described by his own remarks made in 1899, during a demonstration of Marconi's apparatus;

> I used wireless telegraphy before Marconi made his first experiments. I wound a number of turns of insulated cable around U.S.S. *Atlanta,* lying at New York Navy Yard, and likewise around a Navy Yard tug. I sent interrupted current through the *Atlanta's* coil and listened on the tug with a telephone receiver in series with a coil system. I could get signals a short distance away, but not far.

Incidentally, although not recognized as such at that time, this was probably the first instance of the application of the principle of "degaussing". Many years elapsed before this practical application of Fiske's idea would be conceived. In his book, "Electrical Engineering," Sylvanus Thompson noted that Fiske had constructed the largest electromagnet in the world—the 3,000-ton ship *Atlanta.*

In the years preceding World War II, all navies considered it necessary to obtain the best position relative to an enemy force, and at the same time be in the necessary disposition to deliver maximum gunfire in minimum time. This necessitated that many long hours be spent in exact station keeping and in executing complicated maneuvers in all kinds of weather and under all conditions of visibility. Of all the weather conditions, fog was the most dreaded, and many devices were developed to aid navigation under such a weather condition. One of Fiske's experiments, although not connected with the transmission of intelligence without wires, was an attempt to provide a solution of this problem. In his system, the vessels were to take station in column, and each, except the last, was to pay out an insulated wire, supported by a buoy that would be picked up by the ship astern, and connected to a similar permanent wire running the full length of each of the vessels. The fixed installation in the ships was to be a series circuit consisting of a battery and two telephones, one in the captain's cabin, the other, in the charthouse.[8] Today few naval officers will consider that this idea possessed merit.

Fiske continued to manifest interest in the possibilities of radio for naval use. While in the U.S.S. *Petrel* off Chemulpo, Korea, during the summer of 1897, an article in the Scientific American aroused his interest. It occurred to him "That by sending out Hertzian waves of different frequencies, different apparatus at a distance, having vibration periods equal to those of the waves, could be operated." The thought also came to him that if "Only two different instruments at a distance were used, it would be easy to operate one at will without interfering with the other one." Being much interested in the torpedo it seemed that here was a possibility of overcoming one of its principal problems, that of making it maintain a desired course at constant depth. He sketched a simple diagram that day, about which years later he remarked, "It is I believe, at the bottom of all the schemes for using wireless telegraph for directing objects, that have been proposed and used since then." He sent the diagram, with amplifying descriptions to the Western

[7] Bradley A. Fiske, "From Midshipman to Rear Admiral," (the Century Co., 1919), pp. 98–99.

[8] Bradley A. Fiske, "Fleet Telephony", United States Naval Institute Proceedings, March 1907, p. 240.

Electric Co., stating that if the company would patent it in his name, he would assign the patent to them under any satisfactory agreement. He felt that while such was probably ahead of the times, it did appear to have considerable potential usefulness. The proposition was rejected on the basis that it was too far beyond practicality to warrant any expenditures upon it at that time. In the following June, however, Fiske received a letter from the New York manager of Western Electric, advising him that on May 2 he had been instructed to take out the patent and to do whatever else Fiske desired be done. He thereupon prepared and forwarded a patent application with the required papers. Upon his arrival in New York in February 1900, he discovered that his application had not been granted since Nikola Tesla had been granted one for practically the same idea. Fiske states:

> Correspondence with the Patent Office disclosed a curious fact, which the Patent Office admitted, that they had made a mistake in issuing a patent to Tesla while another application for the same thing was being considered in the office.

Through the efforts of the Western Electric Co.'s legal staff, an arrangement was finally made with the Patent Office, whereby Fiske was granted a patent, dated 23 October 1900, underlying Tesla's. During its valid span he made no attempt at practical application of his invention. "Not because", he writes:

> I did not see my way to applying it to steering one torpedo or vessel, but because I did not see my way clear to applying it to steering several simultaneously.

While there were some who gave him credit for the invention, he tells of seeing scores of notices where others in the United States and Europe claimed it for their own.[9]

Fiske's ideas were considered radical and fantastic at the time as was evidenced by the behavior of a battleship commander with whom he was discussing this idea during a casual visit. The captain listened politely, but when he finally understood the young officer's scheme he raised both hands above his head and disappeared down his cabin hatch. Shortly after these experiments, he himself discontinued these efforts and a few years later joined the large group of senior officers of the U.S. Navy who decried the use of radio as a means of naval communications.[10]

THEORIES AND DEVELOPMENTS FOLLOWING HERTZ'S DISCLOSURES

Following disclosure of the knowledge gained by the efforts of Hertz, numerous individuals, in this country and abroad, intensified their efforts to develop a system of telegraphic communications without wires. In 1892, Sir William Preece signaled between two points on the Bristol Channel, Loch Ness, Scotland, employing both induction and conduction to affect one circuit by the current flowing in another. In the same year, another Englishman, C. A. Stevenson, suggested, without experimentation, that telegraphic communications could be established between ships by coils of wire, "the larger the diameter the better to get induction at a great distance." In a lecture before The Franklin Institute, in February 1893, Nikola Tesla described a plan for the transmission of power without wires.

Prof. Edouard Branly, of France, developed his famous coherer in 1892. This device consists of a cell containing a granular conductor between two electrodes. When subjected to an electric current the granules cohere and become highly conductive. Unless the cell is jarred these granules continue to adhere to each other. When utilized in a radio receiving circuit the cell responds to the voltage rise, set up by the impinging radio waves, but afterwards continues to be a good conductor, unless, while the transmitting circuit is opened, it is jarred enough to decohere the granules.

[9] Bradley A. Fiske, "From Midshipman to Rear Admiral," (the Century Co., New York, 1919), pp. 230–231.

[10] Infra, p. 65.

The addition of a trembler, activated by local battery, was a simple solution which required no intricate timing system, since it made little difference if the cell was continuously tapped.[11]

Sir Oliver Lodge is credited as being the first to conceive the idea of using this device for receiving radio signals. His receiver was made up of a spark gap (antenna) across the terminals of the coherer which in turn was also connected in series in a circuit containing a battery and a relay for closing a separate battery-powered local circuit containing the battery, an ink recorder, and the trembler in series. In 1894, he demonstrated this equipment before the British Association for the Advancement of Science.[12] Despite the fact that all the necessary components were at hand, Lodge, occupied with his teaching at the University of Liverpool, neglected to commercialize his system immediately.[13]

The following year, Prof. A. S. Popoff improved Lodge's receiver by the insertion of choke coils on each side of the relay to protect the coherer and by replacing the spark gap with a vertical antenna insulated at its upper end and connected to the ground through the coherer.[14] Popoff utilized his equipment to obtain information for a study of atmospheric electricity.[15] Like Lodge, he was too engrossed with teaching and science to concern himself over its practical aspects. On 7 May 1895, in a lecture before the Russian Physicist Society of St. Petersburg, he stated he had transmitted and received signals at an intervening distance of 6 hundred yards.

In the same year, Guglielmo Marconi, son of an Italian nobleman and an Irish mother, by using a Hertz oscillator and an antenna and a receiver very similar to Popoff's, successfully transmitted and received signals within the limits of his father's estate at Bologna, Italy.

Marconi can scarcely be called an inventor.[16] His contribution was more in the fields of applied research and engineering development. He possessed a very practical business acumen and he was not hampered by the same driving urge to do fundamental research which had caused Lodge and Popoff to procrastinate in the development of a commercial system.

Forseeing little success in commercializing a radio system in Italy, he immediately set out for England [17] where he applied for a British patent on his system, issued, in 1896 as No. 12,039.[18]

Through the efforts of Sir William Preece, and with the asset of a British patent guaranteeing his future rights, he succeeded in obtaining the financial support of wealthy Englishmen. On 20 July 1897, the Wireless Telegraphy and Signal Co., Ltd., was incorporated in England with a capitalization of £100,000. This company paid Marconi £15,000 in cash and £60,000 in stock for his patent in all countries, except Italy and her dependencies,

[11] E. H. Loftin, "Marconi—Father of Radio?" Radio-Craft, Jan. 1937, (Radcraft Publishing Company, Springfield, Mass.), p. 393, Claims A. S. Popoff devised the "tapping circuit."

[12] Maclaurin, op. cit., pp. 18–19.

[13] Oliver Lodge, "Past Years, An Autobiography," (Scribner's, New York, 1932.), p. 113.

[14] Eccles, op. cit., pp. 53–54.

[15] Hawks, op. cit., p. 202.

[16] Sir William Preece: in a lecture before the Royal Institution, London, on 4 June 1897, stated: "Marconi had not discovered any new rays; Columbus did not invent the egg, but he showed how to make it stand on its end; and Marconi has produced from known means a new electric eye, a new system of telegraphy that will be a great and valuable acquisition." Loftin, op. cit., p. 427, states that Marconi, in the 20 years following 1895, obtained only 2 patents.

[17] Orrin Elmer Dunlop, Jr., "Marconi—The Man and His Wireless" (Macmillan Co., New York, 1937.), p. 48, attributes the following statement to Marconi. "I first offered wireless to Italy, but it was suggested, since wireless was allied to the sea, it might be best that I go to England, where there was greater shipping activity, and, of course, that was a logical place from which to attempt trans-Atlantic signaling. Also my mother's relatives in England were helpful to me. I carried a letter of introduction to Sir William Preece. Mind you, Italy did not say the invention was worthless, but wireless in those days seemed to hold promise for the sea, so off to London I went."

[18] The equivalent U.S. Patent, No. 586,193 was granted him on 13 July 1897.

which rights Marconi reserved for himself.[19] The original purpose of the company was to provide radio telegraphy for lightships and lighthouses around the coast of England. In 1900, its name was changed to Marconi Wireless Telegraph Co., Ltd.; its purpose, to establish a worldwide monopoly in radio telegraphy.

In the effort to popularize the concept of monopoly control of wireless telegraphy and to further encourage other British people to invest, wide publicity was given the progress made in increasing the range of the equipment. Paralleling this, much effort was expended in educating people to consider Marconi as "the father of wireless telegraphy." These actions prompted an English writer to publish an article advising that, outside of England and a few of its colonies, other important commercial systems of wireless telegraphy were in more general use.[20] Nevertheless, the founders of the Marconi Wireless Telegraph considered that only the Marconi interests had legal rights in this field and that their patent invalidated the use of radio by others, regardless of the circuitry used. In future years, this claim would be challenged[21] many times and become the subject of considerable litigation.[22] This concept did much to slow the development of radio.

IMPROVEMENT OF MARCONI EQUIPMENT

Immediately after his arrival in England, Marconi began increasing the power of his equipment. By the time the Wireless Telegraphy and Signal Company was formed, he had increased its range to eight miles. With financial support assured, he continued, step-by-step, building more and more powerful apparatus, until, in 1899, he succeeded in transmitting across the English Channel and still later, in 1902, in making the historic transmission across the Atlantic from England to Glace Bay.

On 3 June 1898, Lord Kelvin visited Marconi's Alum Bay station, on the Isle of Wight, and sent from there the first paid radiograms. He had insisted that he be permitted to pay for their transmission, at the rate of a shilling per message, in order to show his appreciation of the system and to illustrate its immediate availability for commercial use. Messages were sent from him to Dr. McLean at Glasgow, Sir George

[19] Marconi testimony, Marconi Wireless Telegraph of America v. *De Forest Radio Telephone and Telegraph Co.*, U.S.D.C., S.D.N.Y., in Equity 8211.

[20] Loftin, op. cit., p. 426.

[21] Commander F. M. Barber, USN (retired) who was keeping the U.S. Navy informed of radio developments in Europe stated in a letter addressed to Chief of the Bureau of Equipment, dated 6 Dec. 1901: "The Germans are wild over the Marconi monopoly. Such a monopoly will be worse than the English submarine cable monopoly which all Europe is groaning under and I hope the Navy Department of the United States will not get caught in its meshes." On November 4, 1935, the Court of Claims rendered decision against the Marconi Co., which claimed U.S. Government infringement of patents of $6,000,000. Page 52 of this 80-page decision, contains the following statement: "Guglielmo Marconi, an Italian scientist is sometimes called the father of wireless telegraphy but he was not the first to discover that electrical communications could be made wihout the use of connecting wire."
Paradoxical as it may appear to the unanimous decision of the august Court of Claims of the United States and indicative of how firmly intrenched an incorrect appellation may become, Congress saw fit in Public Resolution No. 86, 75th Congress, to grant permission to the Marconi Memorial Foundation, Inc., to erect a memorial in Washington to Marconi as the inventor of radio telegraphy, which resolution was approved by the President on April 13, 1938. H. E. Hancock, "Wireless at Sea—The First Fifty Years," (Marconi International Marine Communication Co., Ltd., Chelmsford, England, 1950.), p. 2., quotes a letter of Mr. Kosilev, the Russian Ambassador to Italy, who in reply to an invitation to participate in the celebration in honor of Marconi in 1947, wrote: "We have to inform you that the fiftieth anniversary of the invention of wireless by the Russian inventor Popoff was celebrated in the Soviet Union in 1945 and was followed by a series of official functions and lectures at the Academy of Sciences in the U.S.S.R. For this reason it is not becoming that the U.S.S.R. should be represented at the Marconi celebrations."

[22] W. Rupert Maclaurin, op. cit., p. 276, lists eight litigations instituted by American Marconi Co. in their effort to sustain a monopoly.

Stokes at Cambridge, and to Lord Rayleigh and Sir William Preece in London. The first mentioned one read:

To McLean, Physical Laboratory, University, Glasgow.

Tell Blyth this is transmitted commercially through ether from Alum Bay to Bournemouth and by postal telegraph thence to Glasgow-Kelvin.

On the following day, the Italian Ambassador, not to be outdone, forwarded a long telegram from the same station to the first aide-de-camp of the Italian King.[23]

FIRST RADIO NEWS REPORTING

Radio has been a primary medium for the distribution of news for many years. The Wireless Telegraph and Signal Co. did not underestimate the possibilities promised by this field. The Dublin, Ireland, Daily Express, impressed with the Marconi claims, saw a possible opportunity to "scoop" their competitors. Its owners invited Marconi to radio reports of the Kingston Regatta of July 1898 from the steamer *Flying Huntress,* the first ship fitted with radio equipment for commercial purposes. Marconi stated that his reporting of the races was entirely satisfactory in every respect and that over 700 messages were sent and received during the regatta. Mr. M. V. Snyder, representative of the New York Herald, reported to Mr. James Gordon Bennett, its owner ,the success of the Daily Express' use of radio bulletins. He was later instrumental in bringing Marconi to America for a like purpose.[24]

FIRST USES OF RADIO AS AN AID TO SAFETY OF LIFE AT SEA

Early in 1899 two dramatic incidents focused worldwide attention upon the value of radio for maritime safety. In January of that year, the East Goodwin Sands Lightship, battered by heavy seas and with part of its bulwarks carried away, sent a radio message which quickly brought assistance. Only a few months later, the same lightship had a very narrow escape from sinking when, in a dense fog at 4 o'clock in the morning, 3 March 1899, it was rammed by the steamer *R. F. Mathews* outward bound from London. The East Goodwin Lightship was one of four light vessels marking the Goodwin Sands, and fortunately it happened to be the one with a radio installation. It immediately flashed "We have just been run into by the steamer *R. F. Mathews,* of London. Steamship is standing by us. Our bows badly damaged." Received by the South Foreland Lighthouse, the message was relayed to Trinity House authorities at Ramsgate. Tugs were dispatched, the lightship was towed out of danger and the entire crew saved. It was later proven in Admiralty Court that property to the value of £52,588, had been salvaged by the action resulting from the one short radio report of the accident.[25]

THE FIRST MARCONI COMPANY CONTRACT

Lloyds, the marine underwriter's association, maintained over a thousand agents and subagents, who in addition to other duties as representatives of that corporation, were especially charged to transmit, immediately, all the latest maritime intelligence from their respective districts. As the most extensive single system in the world for the collection, transmission, and dissemination of marine information, Lloyds was naturally interested in any means which would facilitate communication with remote areas. In May 1898, it negotiated with the Marconi Co. for the installation of radio apparatus at some of its signal sta-

[23] H. E. Hancock, "Wireless at Sea," (Marconi International Marine Communication Co., Ltd., Chelmsford, England, 1950.) , p. 13.

[24] Richard Norman Vyvyan, "Wireless Over Thirty Years" (G. Routledge and Sons, Ltd., 1933.) , p. 18.

[25] Navy Times, 24 Mar. 1956, (Army Times Publishing Co., Washington, D.C.) , p. 27.

tions. With his usual business perspicacity, Marconi incorporated the Marconi International Marine Communication Co. on 25 April 1900, a subsidiary of Marconi Wireless Telegraph Co. Ltd. On 26 September 1901, this new company entered into an agreement with Lloyds. Because of the repercussions which followed, the revelation of the monopolistic ideas of the Marconi interests, and the effect their contract policy was to have in later dealings with the U.S. Navy, a brief outline of the Lloyds agreement is of interest. Among other things, it provided for the erection of a series of radio stations on the English coast, the right of Lloyds to have Marconi, and only Marconi, apparatus installed at all their stations, but not the right to utilize it to communicate with ships using radio equipment of other manufacture. Another stipulation required that Marconi apparatus would be used exclusively in equipping ships insured by Lloyds and, except along the coasts of the United States and Chile, these ship stations could not be used to communicate with ship or shore stations not using Marconi apparatus.[26] The contract was to be in force for 14 years, which period covered the life of the Marconi patents then in force. Lloyds found itself unable to establish radio stations at the British colonies of Jamaica, Ceylon, Barbados, St. Helen, Perim, the Straits Settlements and Maritius, because the colonial governments made it a condition of their licenses that intercommunication would be permitted if required by an International Convention.[27]

In its grasping endeavor to establish a monopoly, the Marconi firm was soon faced with a suit over the interpretation of the Lloyds' contract. Lloyds contended, among other things, that the Marconi Co. had refused to equip its shore stations when these were located near Marconi stations. Losing the decision, the Marconi interests entered into a new contract with Lloyds in 1905. Differences were resolved and both organizations agreed to exert their "best efforts" to induce the British and foreign governments to grant no radio licenses to companies other than Marconi and Lloyds.[28]

Credit is due Lloyds for its early faith in and adoption of radio, because until this time communications between passing ships and between vessels and the Lloyds' signal stations had been carried out by flag hoists. To accomplish this, vessels were often required to approach dangerously close to treacherous areas or to make considerable detours from their most direct route.

RADIO TESTS IN THE ROYAL NAVY

The publicity given the Marconi interests and their accomplishments came to the attention of the Royal Navy. In 1899, equipments were placed aboard three ships for tests during summer maneuvers. During July these ships exchanged messages over a distance of 74 nautical miles.[29]

[26] Memorandum on the International Wireless Telegraph Convention concluded at Berlin, Nov. 3, 1906, to Committee on Foreign Relations, Records of Bureau of Equipment, National Archives, Washington, D.C.

[27] Report of Select Committee on Radio Telegraphic Convention, with Proceedings of the Committee, dated 8 July 1907. Records of Bureau of Equipment, National Archives, Washington, D.C.

[28] Maclaurin, op. cit., pp. 37–38.

[29] On 4 July 1900 the British Admiralty entered into a contract with Marconi Co. for installation of their apparatus on 26 ships and 6 coast stations, and for maintenance for a period of 14 years, the life of British patents. Complete apparatus for each ship and station was to be supplied by the company at a cost of £3,200, plus an annual royalty of the same amount during life of the contract. The contract stipulated that each set be tested and operate satisfactorily between Portland and Portsmouth, a distance of 65 miles. Additionally, it required Marconi Co. to train naval signalmen in use of the apparatus at that company's expense. A clause provided for renegotiation of annual royalty in event additional equipments were installed. This lease was the subject of considerable misunderstanding between the Royal Navy and Marconi Co. Under British law, Marconi stood in a somewhat precarious position in attempting to introduce his system into the United Kingdom. By act of Parliament, enacted in 1863, and amended in 1869, the government was given a monopoly over any tele-

graph apparatus for transmitting messages or other communication by means of electric signals. Several attempts were made from time to time to test validity of the government's position, but in every instance it was upheld. In 1899 Marconi Co. applied to the postmaster general for a license to use the system on land in England, but the government refused to grant it. If postal authorities, exercising the monopoly, had been so disposed, they could have compelled Marconi to close all his experimental stations, since he had not received official sanction for them. The Marconi firm, being protected by the Patents Act, the government was placed in the same position as a private individual. Although the government possessed the monopoly, it was unable to adopt the Marconi system without awarding compensation, either by purchasing the system outright, or by payment of royalty. In a later agreement, dated 24 July 1903, the Admiralty solved the problem by awarding Marconi Wireless Telegraph Co. satisfactory compensation for naval installations. This agreement stipulated, among other things, "That they will pay to the Company on the execution of these presents the sum of £20,000 in consideration for the rights and privileges hereby granted and conferred and will also pay the Company within three months from the 31st day of March 1903 on production by the Company of the Certificates stipulated for in the Agreement of the 20th February 1901 the further sum of £1,600, being the amount of the royalty payable to them in respect of the 32 existing installations calculated up to that date. That if the Company shall duly perform its obligations under the Indenture they will pay to the Company on or before the 30th day of April in every year during the said period of 11 years the sum £5,000, the first of such payments to be made in April 1903 and to cover the period until 1904." (Agreement between Admiralty and Marconi Wireless Telegraph Co., Ltd., 24 July 1903, London, files Bureau of Equipment, National Archives, Washington, D.C.). The indenture, from which above excerpts were taken, covers seven pages, which, in brief, spanned a period of 11 years, (expiring in 1914) and granted the Admiralty right to full use of Marconi patents then existing and future, and to exclusive use of a long-distance station for 20 minutes every day, to priority over all other messages, to supply of all apparatus at current prices, and to information concerning any improvement in apparatus or in methods of signaling. (British "Report from the Select Committee on Radio Telegraphic Convention, with proceedings of the Committee", dated 8 July 1907, London, files, Bureau of Equipment, National Archives, Washington, D.C.).

CHAPTER III

Negotiations With the British Marconi Company

EARLY U.S. INTEREST IN RADIO

The Marconi Co. efforts were closely followed and reported by scientific and electrical trade periodicals in the United States. The large eastern newspapers added to the publicity by printing glowing and often exaggerated accounts of the conquering of greater and greater distances. Marconi was granted a U.S. patent covering his system. In England, his company was already claiming complete ownership of this new method of communications. Despite the public interest, little was being done to develop radio communications in this country. Four branches of the Government were considering the possibilities of its use as an extension of telegraphic and cable facilities. As with the English, the U.S. Lighthouse Board took the first step toward establishing its use in this country. Mr. W. J. Clarke, of Chicago, the first American to demonstrate equipment which he hoped to develop commercially, in July 1899, placed a transmitter on a pier of the Lighthouse Board station, Tompkinsville, Staten Island, N.Y., and a receiver on the lighthouse tender *Mistletoe*. While the tender proceeded from Tompkinsville to pier 5, East River, N.Y., the operator transmitted two long signals every 30 seconds. These signals were received during the entire trip and were used to actuate a 4-inch vibrating bell.[1] At this same time the Weather Bureau was considering the use of radio as a means of obtaining weather reports from and providing forecasts to offshore light vessels and isolated localities. Late in that year they sought the services of Prof. Reginald Fessenden of the University of Western Pennsylvania (University of Pittsburgh). In 1900 he entered their employ for the purpose of working out means for its use.[2] Both the U.S. Army and Navy, having experienced communication difficulties during the Spanish American War,[3] saw in the new medium promise of eliminating the unsatisfactory conditions. The U.S. Army Signal Corps had already commenced the development of radio equipment for field communication purposes.

THE U.S. NAVY INDICATES INTEREST IN MARCONI EQUIPMENT

The Navy's interest became intensified by the reports of the successful tests conducted by the Royal Navy during the summer of 1899.[4] The U.S. Naval attaché, London, Lt. Comdr. J. C. Colwell, USN, was directed to obtain information from the Marconi Co. relative to the costs of a demonstration aboard U.S. naval vessels and the prices of equipments. In replying, on 2 September 1899, they stated:

> This Company will be prepared to give a demonstration between two of your cruisers, if your department will bear all out of pocket expenses of our officers while engaged in such work.

[1] Navy Times, 24 March 1956 (Army Times Publishing Co., Washington, D.C.), p. 2.

[2] W. Rupert Maclauren, "Invention and Innovation in the Radio Industry" (the Macmillan Co., New York, 1949.), p. 59.

[3] Supra, p. 13.

[4] Supra, p. 22.

With reference to your question as to whether this Company would sell to the United States Navy two of our instruments to be fitted up on two of their cruisers, this we are not prepared to do. We will, as I mentioned, give you a demonstration for any reasonable time, when your department should be able to decide for how many ships you require instruments. If you will then have not less than twenty of your cruisers fitted up, we shall be happy to undertake the work on a royalty of £2,000 per annum. Should you require a much larger number of vessels fitted with our instruments, some reduction might be entertained on our usual fee of £100 per vessel.[5]

THE NAVY OBSERVES THE RADIO REPORTING OF THE AMERICAN CUP RACES

Following Marconi's successful radio reporting of the Kingstown Regatta, off Dublin, Ireland, in 1898, James Gordon Bennett invited him to report the 1899 America Cup Race, between the *Shamrock* and the *Columbia*, for the New York Herald. The invitation was accepted.[6]

Marconi's trip to the United States was in no manner connected with the increased interest of the U.S. Navy in radio and the Marconi equipment. The Bureau of Equipment was very anxious to have his equipment tested in order that it might be evaluated for Navy use. His impending arrival in this country, with personnel and apparatus, was looked upon as an opportunity for conducting these tests at small cost. In a letter to the Secretary of the Navy, dated 18 September 1899, Rear Adm. Royal B. Bradford, U.S. Navy, Chief of the Bureau of Equipment, stressed this point among others, and requested the

Department to take the matter into consideration and instruct the Bureau if the necessary facilities including the use of proper ships and officers, will be available for the tests.[7]

In replying the Secretary directed him to make arrangements for naval officers to be present to observe the workings of the Marconi equipment during the yacht races and to arrange for later tests of the equipment in a battleship, a cruiser and a torpedo boat.

Following Marconi's arrival in New York on 21 September, arrangements were made with him for a group of naval officers to witness the operation of his equipment during the conduct of the races. The Navy Department designated a group of observers, sometimes known as the Marconi Board, which consisted of Lt. Comdrs. J. T. Newton and E. F. Qualtrough, and Lts. John B. Blish and G. W. Denfeld, USN. All four were electrical experts and were well qualified to pass judgment. In order that each officer could thoroughly investigate the operation of the system, the instructions required them to exchange posts and each to submit his own observations on the nature and operation of the Marconi equipment.

The Highland Light, Highlands of Navesink, N.J., was selected as the shore terminal of the reporting circuit and the necessary equipment was installed there. The SS *Ponce* of the Puerto Rico Line and the cable ship *Mackay Bennett* were provided and equipped as the sea terminals. The latter was anchored near the Sandy Hook Lightship, where it picked up and tapped a transatlantic cable in order to relay radio bulletins by cable to England and, if necessary, to New York City. A third ship, the SS *Grande Duchesse*, jointly sponsored by the Plant Line and the Marine Journal of New York, was equipped with the radio apparatus of Mr. W. J. Clarke.

[5] Letter, dated 2 Sept. 1899, Marconi Wireless Telegraph and Signal Co., Ltd. to Lt. Comdr. J. C. Colwell, USN, files, Bureau of Equipment, National Archives, Washington, D.C.

[6] ("Radioana," SRM–173–009, Massachusetts Institute of Technology, Cambridge, Mass.). Pro. Amos Dolbear, of Tufts College, holding a basic U.S. patent on an induction system of communication, notified Marconi, upon his arrival in this country, that he would be restrained, but later through courtesy allowed him to report the yacht races. ("Radioana" is a large collection of material on the early history of radio cataloged and reposited by Mr. George Clark).

[7] Letter, dated 18 Sept. 1899, files, Secretary of the Navy, National Archives, Washington, D.C.

On 7 October, Qualtrough went to sea on the *Grand Duchesse* and witnessed the working of the equipment. Although the apparatus was of different manufacture, messages were transmitted and received between the *Mackay Bennett* and the *Grande Duchesse,* without difficulty, for one hour.[8] The *Ponce* became unavailable and on 10 October the Marconi apparatus was moved to the *Grande Duchesse.* Clarke's equipment was not used from that date.

Lack of wind resulted in numerous "drifting contests" which dragged out the races from late September to 20 October. At this time Admiral George Dewey was returning to the United States in the U.S.S. *Olympia* following the battle of Manila Bay. He had cabled the Navy Department that he anticipated arriving in New York on 30 September. Marconi was persuaded to go to sea for the purpose of contacting and boarding Dewey's flagship and reporting her progress, via the station at the Highlands of Navesink. Equipment was hurriedly installed in an ocean-going tug which started down the bay on September 28th, only to meet the *Olympia* plowing through the fog, 2 days ahead of schedule. Had not her firemen kept up a full head of steam all the way across the Atlantic, the Navy would have been able to radio the news of her triumphant return long before the press and would have scored its first radio scoop.

Two days later, a naval parade was held, in honor of the Admiral, in which the *Ponce* was assigned a position. During the parade Blish sent the following message:

Bureau of Equipment, Washington, D.C.
From Steamship *Ponce*, underway in Naval Parade via Navesink Station.

Mr. Marconi succeeed in opening telegraphic communication with shore at 12:34 p.m. Experiments were a complete success.
/S/ Blish, Lieutenant USN

Transmitted personally by Marconi, this was the first paid ship-to-shore radiogram and the first official U.S. naval radio message.[9]

Weather conditions finally changed and the America Cup Races were completed. They were successfully reported. Almost as much publicity was given Marconi and the reporting media as was given the winner. The potentialities of this new mode of communication for maritime purposes was well impressed upon the American public. Scientific interest was heightened which later resulted in increased effort on the part of U.S. scientists and engineers.

The naval observers noted the workings of the equipments, both afloat and ashore, but were limited in their observation by the actions of Marconi and his assistants. Following the first day of the races, Qualtrough exuberantly commented to a Herald reporter:

> If we could only have had this last year, what a great thing it would have been. When we landed marines in Guantanamo, the ships were unable to lend assistance, for the reason that the enemy could not be located, and firing at random would have placed our forces in danger. With the aid of the Marconi system, the men ashore would have directed the fire. The English sent a Marconi apparatus ashore with every landing party. In the Philippines, the system would right now be of great service to us.

On 9 November 1899, Newton forwarded the separate reports of the observers to the Secretary of the Navy.[10] In this, he stated

[8] This cooperation must be considered an error of judgment on the part of Marconi. At this time and for the next several years, in their endeavor to establish the monopoly, his company insisted that, if proper results were to be obtained, it was essential that the receiver and transmitter be of the same manufacture.

[9] George H. Clark, "Radio in War and Peace," p. 6, "Radioana," Massachusetts Institute of Technology, Cambridge, Mass.

[10] Letter, dated 9 Nov. 1899, files, Bureau of Equipment, National Archives, Washington, D.C. A portion of Denfeld's description of Marconi equipment as contained in this letter is summarized: "The Marconi apparatus installed at each station consisted of a transmitter operated by a storage battery with a capacity of 6 amperes and 18 volts, the storage battery being charged by 98 Obach cells connected in series multiple (14 cells in series with 7 groups). The receiver (coherer) was enclosed in a rectangular box which also contained transformer, choking coils, tapper, and a single-cell battery. A separate battery of eight cells was used for working the tapper and the Siemen's recording instrument. At Navesink the antenna was supported from a

that he was favorably impressed with the system but said it appeared to be questionable if the receiving apparatus could generally record a message with sufficient accuracy to ensure the consequent transmission of a cipher code. He was of the opinion that fog had an effect on the clearness of transmission.

Blish, commenting on the restrictions placed upon his observations stated:

> My official and social relations with Mr. Marconi and his four assistants during this time and the remainder of their stay in this country were most pleasant, but at no time did any of them describe or explain the apparatus more fully than had already been done in public print, and their answers to questions never gave any information beyond this. Usually their answer was that the information was withheld until a patent covering the point in question had been secured; frequently the answers given by different members of the party were conflicting, and sometimes it appeared that their answers were intended to mislead.

He was of the opinion that if such apparatus were installed on vessels of the Navy, the care and operation of the system would require men with about the same intelligence, education, and length of training then required for naval electricians.[11]

The concluding paragraph of Denfeld's report commented upon the possible value of the equipment:

> The apparatus cannot be considered perfect, but Signor Marconi gave a practical demonstration which showed that even in its present state the instruments can be made useful in signaling between ships and shore, and there is a certainty of working under all conditions of weather which is not common to any other mode of communication at sea.

The *Ponce* was reported as having transmitted approximately 2,500 words during the first day, at an average speed of about 15 words per minute. One speed test produced 31 words in 1 minute and 50 seconds, or about 17 words per minute. Qualtrough estimated that the extreme distance at which messages were sent and received was about 17 miles. Another estimate stated 17 miles with a 120-foot antenna and 24 miles with a 150-foot one. During the course of the races it was claimed that 1,200 messages containing an approximate total of 33,000 words were transmitted and received.[12]

Previous to 30 September, the date on which Blish sent the message stating that the system worked perfectly, officials of the Navy Department had been inclined to be skeptical. After the trials comment in the Capitol was optimistic and a Washington newspaper reported Rear Adm. Bradford as being very much pleased with the reported success of the tests.

NAVAL TESTS OF MARCONI EQUIPMENT

During the progress of the America Cup Races, an agreement to conduct tests of his equipment aboard U.S. naval vessels was reached with Marconi. Prior to agreeing, he had demurred on the grounds that the

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gaff fitted to the flagstaff. On vessels they were suspended carefully from masts and carefully insulated from them. These antennas were of insulated wire, about 100 to 130 feet long. In leading them into the rooms containing the apparatus, great care was exercised to ensure that the insulation was satisfactory. During transmissions of messages the antenna was connected to one of the knobs of the secondary winding of the transmitter and the other knob was connected to earth. These knobs were about eight-tenths of an inch apart. The telegraph key was in series with the primary winding of the coil. When the telegraph key was closed, sparks between the knobs made a noise similar to striking several matches. When receiving messages, the antenna was disconnected from the transmitter and secured to one terminal of the primary winding of the transformer, while the other end of this winding was grounded. From the transmitter, the antenna was rapidly charged and discharged, thereby producing an electrical effect which acted on wire in a receiving antenna in a manner which reduced resistance in the receiver which was either in series with the second wire or in a circuit with one of the transformer coils, the other coil being in series with the antenna. When resistance of the receiver circuit was sufficiently reduced, the local battery energized it, and the dot or dash was recorded.

[11] "Radioana," SRM 100, op. cit., p. 2.

[12] Orrin Elmer Dunlop, Jr., "Marconi—The Man and His Wireless," (the Macmillan Co., New York, 1937), p. 80.

equipment provided for the races was short range, only sufficient for the distances required by the races, and was not the type of equipment his company fitted into naval vessels. He further stated that with the available equipment he would not be able to obtain results comparable with those obtained in the British Navy maneuvers of the previous July. He claimed it would be necessary to equip the Navesink Light station with a set of apparatus which did not incorporate his latest devices. Under the circumstances, he could not guarantee the results at that station, a fact he wished known and accepted before the trial.

Rear Adm. N. H. Farquhar, USN, Commander in Chief, U.S. Naval forces on the North Atlantic station, was placed in charge of the tests. Marconi conferred with him and they made all necessary arrangements on his flagship the armored cruiser, U.S.S. *New York,* on 22 October. He requested an overall height of 150 feet, for antenna installations. This necessitated adding special spars to the masts of the U.S.S. *New York* and *Massachusetts,* the two ships which were to be equipped. It was agreed that during the tests visual signaling would be dispensed with, and that all orders of the admiral would be

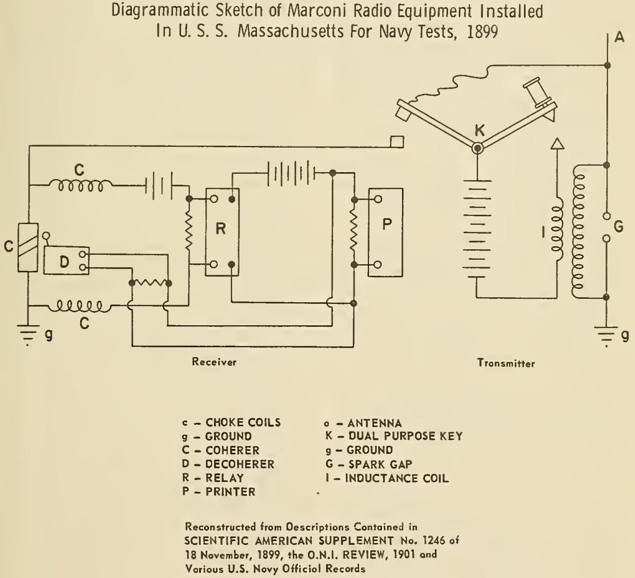

FIGURE 3–1.

transmitted by radio telegraph. A later test was to be made with one set of equipment installed in a torpedo boat. The apparatus from the *Grande Duchesse* was placed in the *New York,* that from the Highlands in the *Massachusetts,* and the set which had been on the *Mackay Bennett* was set up at the Highlands station. Marconi and his assistants made the ship installations. Blish, one of the Bureau of Equipment representatives, was detailed to make the necessary arrangements for getting the instruments to the ships. On 23 October 1899, Secretary of the Navy Long appointed the members of a wireless telegraph board for the purpose of investigating the Marconi system of radio telegraphy to be tested in the U.S.S. *New York, Massachusetts* and *Porter* and at the Navesink Lighthouse.[13] Newton was designated senior member of the board and Blish and Lt. F. K. Hill, USN, members with orders to report for duty to the Commander in Chief of the North Atlantic station, and by letter to the Chief of the Bureau of Equipment.

In a letter, dated 20 October 1899, Chief of the Bureau of Equipment requested Admiral Farquhar, to obtain, by tests, the following information:

Suitability for use in squadron signaling under conditions of rain, fog, darkness, and motion of ship;
Accuracy of receiving letters or figures, using words in signal code as a test;
Possibility of receiving messages when the ships are close together;
Greatest distance that messages can be exchanged between Navesink Station and one of the ships;
Best location of instruments;
Danger of fire, due to faulty insulation with such high potentials;
Result of two transmitters operating at same time;
Method used to overcome interference; and,
Such other information as may appear desirable during the conduct of the trials.[14]

The installations [15] were completed and the initial tests were commenced on 26

[13] Letter, dated 23 Oct. 1899, Secretary of the Navy to Lt. Comdr. John T. Newton, files Bureau of Equipment, National Archives, Washington, D.C.

[14] "Report of Board on Marconi System of Wireless Telegraphy", n.d., files Bureau of Equipment, National Archives, Washington, D.C.

[15] The aerials employed were, in each case, a rubber-insulated single wire, made of seven copper strands, each 1/25-inch in diameter. Three ebonite rods, each 18 inches long and 1 inch in diameter, suspended in series, formed the aerial insulator at the top of the wire. The temporary wooden masts attached to the topmast of each battleship had an 18-foot sprit hoisted to the top by halliards bent on, at about one-third of its length. The aerial was attached to the longer end while the shorter one was held steady by a down haul keeping the wire away from lightning conductors on the masts and from metal rigging. The antenna was, therefore, more or less of the vertical type, being at an acute angle with the mast, and extending from the top of the sprit to the after gunroom, where it was attached to the wireless apparatus. The upper ends were 130 feet and 140 feet, respectively, above decks of the *New York,* and the *Massachusetts.* At the Navesink station, the upper end was 150 feet above ground. On torpedo boat *Porter,* used later in the tests, the upper end of the antenna was only 45 feet above deck. The detector was the coherer, with each of the telegraph instruments being equipped with a Morse inkwriter, so that messages received were recorded on tape. Some sources state that a plain antenna circuit was used; i.e., that the coherer was directly in series between antenna and ground; others that a coupling transformer was employed. The former view was held by Mr. W. G. Richards of Marconi's Wireless Telegraph Co., Ltd., London, who, after searching the company files, reported that circuits used during yacht races were plain circuits. On the other hand, Blish states that a coupling transformer was used, and shows a diagram of the receiving circuit with that device included. (U. S. Naval Institute Proceedings, 1899, vol. 25, pp. 861–863.) Marconi's letter to the Navy Department, stating that he had not used his tuning apparatus in America for patent reasons, would appear to support Mr. Richard's opinion. (Radioana, SRM 100–197, SRM 82–97, Massachusetts Institute of Technology, Cambridge, Mass.). Clark's account ("Radio in War and Peace," pp. 7–8) reports that a spark transmitter was used, with the spark gap in the antenna directly, with no coupling of any sort being employed. An induction coil, fed by storage batteries, excited the gap. The transmitted wave was dependent entirely on length of antenna, and the signal emitted was very broad. The receiver was slightly more refined, as an induction coil was used to connect the antenna circuit to the dector. This coil was not tuned but was intended merely to raise the voltage which operated the coherer. Frequencies transmitted by the two larger ships and the shore station were about the same. Since all three stations had antennas approximately the same height, they were tuned to each other as closely as was necessary. However, in the later test between Highlands Station, with an antenna of 150 feet, and torpedo boat *Porter,* with a antenna height of 45 feet, the latter's frequency was about three times that of the others.

October. The first of these was one to determine the suitability of the equipment for tactical signaling by testing the speed and accuracy of the instruments at moderately close distances, under favorable conditions. As there was no need for the ships to be underway, they were anchored in the North River, one off 34th Street and the other off 38th Street, about 488 yards, or cruising distance apart. A variety of messages were exchanged, with practically no errors, at an average speed of about 12 words per minute, which was considerably slower than the sending of Marconi while reporting the yacht races. These messages consisted of items from newspapers, series of numbers, mixed alphabet and encoded and enciphered items. Legibility ranged from "good" to "very good" the first day, but "not good" to "good" on the following.[16] In writing of these short range tests Marconi, apparently with no knowledge of the requirements of tactical signaling, commented:

Curiously enough, one of the first requests of the officers was for official proof that the system could be operated for short distances, and two or three days were spent in the East River signaling a few hundred feet.

Listening only to Marconi's criticism and without endeavoring to gain any understanding of the reasons for the short range tests the New York Times commented:

. . . Is there not something a little provocative of smiles in the 'tests' of wireless telegraphy now making by the Navy Department? It was so very well known to all who have paid the slightest attention to the operations of Signor Marconi that much more can be accomplished by the aid of his device than was attempted in Thursday's experiments! To send signals and messages between warships anchored a few hundred feet apart is a task vastly easier than others which he performed with complete success months and months ago, and surely our naval officials should not need to enter the primer class in this method of communication. There was a trace of deserved sarcasm in the inventor's tone when he said that the telegraphing done on this occasion was a trial of the operators' skill, not of the system. The curious slowness of the Government in taking up new ideas and new implements has often had expensive consequences, and more than once it had had tragical ones, as in the case of smokeless powder and high-power rifles. At present, apparently, they are tempting the laughter of foreigners by treating as novel things that have long been matters of common talk among amateurs and professional scientists alike.[17]

In the next tests, which were for the purpose of determining the ranges of the equipments, the *New York* was anchored about 5 miles off the Highlands of Navesink, while the *Massachusetts* proceeded to sea. At 10-minute intervals, messages were successfully exchanged up to 36.5 miles. The *Massachusetts* was able to receive the *New York's* transmissions up to 46.3 miles. The curvature of the earth was blamed for restricting the range,[18] despite the fact that this had been disproved in the July maneuvers of the Royal Navy. At the time the theory prevailed that the distance of transmission depended upon the vertical component of the aerial and varied as the square of the height of the upper end of the wire above the instruments, or above the hull of an iron ship, when the instruments are placed below the upper deck.[19]

On 31 October, during a very heavy northeast gale, accompanied by almost constant rain and under conditions regarded as most unfavorable, the tests were continued between the two vessels, with the *Massachusetts* anchored inside Sandy Hook and the *New York* anchored in Gravesend Bay. The elements presented no disturbing effects on transmission and reception, and satisfactory results were obtained.[20]

On 2 November, with the storm unabated, Marconi in the *New York* transmitted the first official naval radio message sent from a U.S. naval vessel. The 4 Novem-

[16] Report of Board on Marconi System of Wireless Telegraph.

[17] The New York Times editions of 1 November 1899.

[18] Dunlop, op. cit., p. 81.

[19] John B. Blish, U.S. Naval Institute Proceedings, 1899 vol 25 p. 861.

[20] Letter, dated 2 Nov. 1899, Rear Adm. N. H. Farquhar to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

ber 1899 edition of the New York Herald contains this item:

Rear Admiral Phelps received the first official message of wireless. Rear Admiral Farquhar, on his flagship, the *New York,* twenty miles at sea, presented his compliments to the Commandant and reported that he would be at the Navy Yard on Friday morning to refuel. The message was ticked off from the transmitting spar lashed to the topmast of the *New York,* caught by the receiver at the Navesink Station 20 miles away; then it was sent over the wires to the Navy Yard. Admiral Phelps immediately acknowledged the receipt of the message and reported that the coal dock would be made ready for the *New York.*

When Admiral Farquhar called Admiral Phelps yesterday morning, the latter asked "Did you get my message?" "Perfectly," said Admiral Farquhar, "It was rather startling to get word from you, whom I knew to be cozy and comfortable in your office, while we were tossing about out there in a lively gale."

The results of the interference tests were perfect. That is, the interference was perfect. From time to time the land station transmitted signals while one ship was receiving from the other, which always resulted in utter confusion with the tape being rendered absolutely unintelligible. Concerning this defect it was reported:

When signals are being transmitted from one station to another, as between the U.S.S. *New York* and the Highlands Light, and another vessel comes within signaling distance and attempts communication with the Highlands Light, then the signals from the two ships become confused, and the receiving station on shore is unable to distinguish between them. Mr. Marconi claims he could overcome this defect, but did not do so. It is said that he has since perfected apparatus which will, in a mesaure, accomplish this result.[21]

In a letter to the Wireless Board, dated 29 October 1899, Marconi stated:

Having consulted with my partners, I regret being unable to give a demonstration of the device I use for preventing interference, and of the system employed for tuning or synchronizing the instruments. The reasons why I cannot give such demonstrations are: (a) the means employed are not yet completely patented and protected, (b) insufficient material and instruments here with me to give a full demonstration, and (c) no detailed information from the United States Navy Department was received by my Company, prior to my departure from England, as to the extent of the demonstrations required; therefore the instruments sent here were solely necessary for carrying out our contract with the New York Herald, and sufficient for a Government test not on a large scale.

This was very disappointing, but, since the three installations were operating on about the same frequency the result was inevitable. If the same experiment were to be repeated today with broad-band transmitting equipment, on approximately the same frequencies, the results would be the same. The inability to employ tunable equipment at the time was unfortunate, for impressions developed about the inevitability of interference with the Marconi equipment which persisted for years.

Upon the completion of the *Massachusetts-New York* tests the equipment from the latter was removed and installed in the torpedo boat *Porter.* The *Porter* spent a day steaming about the *Massachusetts,* off the Highlands, conducting tests to determine to what extent the reduced aerial height with the resultant change in frequency of the *Porter* installation would limit communications. The *Massachusetts* was able to receive the *Porter* for a distance of 8.5 miles and the *Porter* received the *Massachusetts* a distance of 7 miles.

The New York Herald, which had given thorough cover to both the yacht races and the Navy tests, had great faith in the future of radio telegraphy. In its issue of 21 January 1900, it came out with the following prediction:

The day of the flag and lamp signaling system in the Navy is drawing to a close. The Dewey of the next war, instead of signaling the course to be pursued by means of lights, as Dewey did when he entered Manila Bay, and thus exposed his position to the enemy watching on Corregidor Heights, will send out electric waves.

In making this prediction, little did they realize or understand that the visual observation of the blinking light disclosed Dewey's fleet at an infinitesimal distance as compared with the distant locations obtained on ships making radio transmissions during later wars.

[21] Annual Report of the Secretary of the Navy, 1900, pp. 319–320.

The trials were not fully completed when Marconi was requested to return to England [22] to prepare apparatus for use in the Boer War.[23] Always extremely anxious to do his utmost to be of service to the British Government, he made immediate arrangements to return. The remainder of the tests were cancelled.

Prior to his departure he stressed the advantages of his system, particularly its cheapness and the ease and rapidity with which it could be transported and installed. Picking up the theme of Qualtrough's earlier exuberant remarks, he pointed out how valuable his equipment would be in the occupation of territory and for communication between ships and shore as well as between ships. In a caustic letter addressed to the Navy Department he noted, among other things, that he had had no inkling before leaving England on September 12 that the Navy desired him to give a complete demonstration, and that therefore he had not brought the apparatus suitable for the tests desired. This is at variance with the letter from the Wireless Telegraph and Signal Co., Ltd., to the naval attaché, London.[24] Moreover, the time between the dates of the agreement and the beginning of the tests was more than enough to have permitted shipping the equipment from England. Since the Marconi interests had something to sell to a potentially large customer, the burden lay upon them to see that their latest and most suitable equipment was demonstrated.

REPORT OF THE NAVY'S RADIO TELEGRAPH BOARD

During the tests the instruments had been open to the inspection of the naval officers, except that certain parts were never dismounted for close scrutiny. Their workings were explained only in a general way, and when questioned, Marconi and his assistants always give vague and conflicting replies or excuses, as to why they could not provide the information.[25]

The Board submitted its report on 4 November 1899, portions of which are quoted:

It is well adapted for use in squadron signaling under conditions of rain, fog, darkness and motion of ship. The wind, rain, fog, and other conditions of weather, do not affect the transmission through space, but dampness may reduce the range, rapidity, and accuracy by impairing the insulation of the aerial wire and the instraments. Darkness has no affect. We have no data as to the effects of rolling and pitching, but excessive vibration at high speed apparently produced no bad effect on the instru-

[22] Marconi returned to England on the S.S. *St. Paul.* Ever alert for any opportunity to offer proof of practicality of his apparatus and to obtain publicity for his company, before departing New York he cabled his London office that he would speak to Needles station from the ship on arrival in English waters. On the afternoon of 15 November 1899, he established communication with this station 60 miles distant and had them transmit news bulletins. With these, the ship published The TransAtlantic Times, vol. I, No. 1., first ship's newspaper to contain news reported by radio. Capt. J. C. Jamison issued instructions for preparation of a souvenir of this event. Copies of this first issue were sold for $1 each and were available to passengers and crew just before the ship docked at Southampton.

[23] While in America, Marconi's experiments in peacetime operations induced him to remark at the conclusion of the America Cup Races, "I'd like to try the system in war" ("Wireless Telegraphy in War," Professional Notes, The Proceedings of the United States Naval Institute, vol. XXVI, no. 3, September 1900, p. 535). Opportunity soon presented itself, when the British War Office adopted Marconi apparatus for use in the Boer War. Within a month of the outbreak of hostilities 6 of his assistants departed for the front, taking 32 sets of instruments (New York Herald, 8 Nov. 1899). These did not prove of great value to the British Army in the field. Since they were not easily transportable at a time when that factor was a major problem, they became an unwanted burden. Some sets were transferred to the British naval squadron blockading Delagoa Bay and others were set up on shore to provide land terminals for the blockaders. The Marconi personnel confined their attention to the task of communicating between warships patrolling coast and shore stations (Op. cit., Proceedings of the United States Naval Institute, p. 536). The Boers ordered radio equipments from a European firm (New York Herald, 31 Dec. 1899). This equipment was delivered too late to be of any value.

[24] Supra, p. 25.

[25] Letter, dated 2 Nov. 1899, Rear Adm. N. H. Farquhar to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

ments and we believe the working of the system will be very little affected by the motion of the ship.

The accuracy is good within the working ranges. Cipher and important signals may be repeated back to the sending station if necessary to insure absolute accuracy.

When ships are close together (less than 400 yards) adjustments (easily made) of the instruments are necessary.

The greatest distance that messages were exchanged with the station at Navesink was 16.5 miles. This distance was exceeded considerably during the yacht races when a more efficient set of instruments was installed there.

The best location of instruments would be below, well protected, in easy communication with the commanding officer.

The spark of the sending coil or of a considerable leak due to faulty insulation of the sending wire would be sufficient to ignite an inflammable mixture of gas or other easily lighted matter, but with the direct lead (through air space if possible) and the high insulation necessary for good work, no danger of fire need be apprehended.

When two transmitters are sending at the same time all the receiving wires within range receive the impulses from transmitters, and the tapes, although unreadable, show unmistakably that such double sending is taking place.

In every case, under a great number of varied conditions, the attempted interference was complete. Mr. Marconi, although he stated to the Board before these attempts were made, that he could prevent interference, never explained how nor made any attempt to demonstrate that it could be done.

Range of signaling: Between large ships (heights of mast 130 and 140 feet above the quarter deck) the range is at least 35 sea miles at sea and 16.5 miles or less when tall buildings of steel frames interfere.

The rapidity is not greater than 12 words per minute for skilled operators.

The shock from the sending coil of wire may be quite severe and even dangerous to a person with a weak heart. No fatal accidents have been recorded.

The sending apparatus and wire would injuriously affect the compass if placed near it. The exact distance is not known and should be determined by experiment.

The system is adapted for use on all vessels of the Navy including torpedo boats and small vessels as patrols, scouts and dispatch boats, but it is impracticable in a small boat.

For landing parties the only feasible method of use would be to erect a pole on shore and then communicate with the ship.

The system could be adapted to the telegraphic determination of differences of longitude in survey.

The Board respectfully recommends that the system be given a trial in the Navy.

On 1 December 1899, the Chief of the Bureau of Equipment forwarded the report, with his comments and recommendations, to the Secretary of the Navy. The salient portions of his letter stated:

The report of the officers detailed to witness the use of this system during the late International Yacht races and of the board appointed to carry on experiments on board of the *New York, Massachusetts* and at the signal station established at the Highlands of Navesink, indicates that this system is successful and well adapted for Navy use. The chief objection to it is known as "interference," which may be described as follows: When signals are being exchanged between two stations, if signals are made at a third station within the radius of effect then the signals at the receiving station of the first two mentioned become confused and unintelligible.

Notwithstanding this fact, the Bureau is of the opinion that the system promises to be very useful in the future for the naval service. So far as the Bureau is able to learn this system is now in use.

(a) In the Italian Navy.

(b) In the French Navy.

(c) In the British Navy.

(d) At the East Goodwin Lightship and the South Foreland Light-House.

(e) At several other permanent shore stations in England and at least one in France.

(f) It is reported that it is to be supplied for use in the British Army in South Africa.

It does not appear that any makers of electrical instruments have been able to successfully duplicate Marconi's apparatus.

If attempts were made, the result would undoubtedly be expensive and success problematical. It would also involve a risk of an injunction or patent suit.

Although the validity of the Marconi patents have not yet been tested, he is the recognized successful inventor and practitioner of wireless telegraphy.

At the request of the Bureau, the Naval Attache' in London addressed an inquiry to the company having Mr. Marconi's apparatus in charge, with the view of ascertaining the cost of instruments successfully used in this system. A response was received to the effect that not less than 20 sets of instruments would be supplied and that cost of these 20 sets would be $10,000 and a royalty of $10,000 would be required for their use per year, making the expenditures necessary for instruments and the right to use for the first year $20,000 and for each succeeding year $10,000. It was stated that a reduction in the royalty would be made if a greater number of instruments were purchased; the purchase including the right to manufacture and to use all improvements adopted in the future by the company. It does not appear probable, owing to the success in recent experiments that these prices will be reduced. The appropriations of the Bureau will not admit of the expenditures above mentioned.

It is probable that instruments can be purchased or manufactured in this country sufficiently accurate for use for a distance not exceeding 2 miles.

Should it be deemed advisable to adopt the Marconi system in the naval service, which the Bureau recommends, the first step necessary is to instruct a certain number of officers and men in the use of the apparatus. Lieutenant J. B. Blish, USN, now attached to this Bureau is deemed competent for this duty.

It is therefore suggested that at some suitable place two stations be established with this end in view.

It is suggested that Newport, R. I. is a suitable place for the purpose, one station being established on Goat Island at the Torpedo Station and the other on Coasters Harbor Island at the Training Station.

In addition instruction in this method of signaling could be incorporated in the yearly course of instruction for officers in electricity at the Torpedo Station.

There are at both places quarters for men which is an important item; there are also in connection with both stations the necessary facilities for the work. The rough imitation instruments above-referred to, which would cost under $1,000 can be supplied by this Bureau and will be sufficient probably for all purposes of instruction. There are also light-houses in the vicinity available for more distant stations and there are tugs and boats available for such service afloat as will be required.

No other station, so far as the Bureau is informed, offers as many facilities as Newport for this duty.

Should the Department decide to establish the above mentioned station, further details of requirements can be furnished by the Bureau.

The Bureau recommends that this station for instruction be established forthwith.[26]

MARCONI'S PROFFER UNACCEPTABLE TO THE NAVY

There is no available record of the discussions which followed the Secretary's receipt of this letter. Later information would indicate it probable that he pointed out the illegality of obligating unappropriated funds. It is also possible that the refusal of the War Department to accept Marconi's stipulation may have had some bearing. In any event the Chief of the Bureau of Equipment changed his mind shortly after making his favorable recommendation. The New York Herald, 4 December 1899 edition carried the following news item, under a Washington, D.C. date of the previous day, which stated:

> After the Naval experiments, Rear Armiral Bradford communicated with Signor Marconi and requested him to state the figure at which he would sell twenty sets of instruments. Mr. Marconi declined to sell, but said that the Navy would have to pay $10,000 down, and $10,000 a year, for the twenty sets. Rear Admiral Bradford thought this a high price, and it is proposed to purchase the various parts for the instrument and assemble them. It is said there can be no infringement of patents, as, with the exception of a few parts, the wireless telegraphy system is common property, and the Signal Corps of the Army is now experimenting with instruments devised by its own officers.[27]

Following this, it does not appear that the Marconi Wireless Telegraph Company of America [28] made any endeavor to obtain the contract. It is possible that Marconi,

[26] Letter, dated 1 December 1899, Chief of Bureau of Equipment to Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C. Although equipment was assembled and erected at Newport, R. I., it was not officially established as a radio school and quickly fell into disuse.

[27] Capt. Samuel Reber, Signal Corps, U.S.A., witnessed tests of Marconi equipment as representative of the War Department. He recommended that the Department reject a similar offer. At this time the Signal Corps had assembled equipments and established one circuit between Fire Island, N.Y., and Fire Island Lightship and another between Governor's Island, N.Y., and Fort Hamilton, N.Y. (George H. Clark, "Radio in War and Peace," unpublished manuscript, n.d., pp. 6–7).

[28] While in the United States, Marconi and several business associates, who had crossed with him, established the Marconi Wireless Telegraph Company of America. It was incorporated under laws of the State of New Jersey on 22 November 1899 with sole rights to exploit Marconi patents in the United States, its possessions, and Cuba, except a newly established Hawaiian interisland system, which was retained by British Marconi Co. Of the 2,000,000 shares of $5.00 par value stock authorized in the American affiliate, the British parent firm held 365,000 shares and Marconi was given /600,000 shares for American rights to his patents, present and future.

feeling secure with his U.S. patent, directed them to await further overtures from the government services. If so, they waited in vain.

In the light of future events, the Marconi leases and stipulations have proved a blessing in disguise. The foresight of the authorities in not permitting themselves to be shackled with its restrictions, which would have persisted for more than a decade, allowed the Navy a free hand in guiding and assisting in the development of radio in this country. The nonacceptance of unwarranted, dictatorial authority led to a wider search, the exercise of ingenuity, and the more rapid development of a competitive market which benefitted the Navy and the rest of the world.

CHAPTER IV

The Unhurried Search for Radio Equipment

WATCHFUL WAITING

After rejecting the monopolistic tenders of the Marconi interests, the Navy decided to study the situation carefully, prior to making a decision, believing that a policy of watchful waiting would prove more beneficial in the long run and that the time lost would be regained by the eventual acquisition of improved equipment. Two years were spent in this manner.

ORGANIZATION OF EARLY U.S. RADIO COMPANIES

During this time, several American scientists and engineers began endeavors to develop equipment, which they hoped would not infringe the patents of Marconi, and companies were organized to exploit their work. As previously mentioned, W. J. Clarke had already demonstrated equipment to the U.S. Lighthouse Board.[1] The American Wireless Telephone & Telegraph Co.[2] was incorporated in September 1899 and thereby earned the distinction of being the first radio firm in the United States. This company was organized by a clique of promoters in Philadelphia, Pa., headed by Dr. G. P. Gehring, a broker of questionable real estate and gold mines. His first move was to obtain control of some patents taken out 15 years earlier by Professor Dolbear, which had been forgotten but were revived by the increased interest in radio. Subsidiary firms were incorporated in the areas in which they purported establishing radiotelegraph circuits. To provide the promoters with a veil of honesty, these firms were officered by prominent and honest personages living in the area covered by each. Gehring's primary interest in radio was its exploitation for stock-promotion purposes.[3] The Dolbear patents were soon discarded in favor of equipment developed by Prof. Harry Shoemaker and Mr. John Greenleaf Pickard, the capable and honest engineers of the corporation.[4] Had Gehring and his associates endeavored to sell this equipment, instead of worthless stock, the company might have developed into an important factor in the radio field.

At the time Marconi was getting firmly established in the radio field, Mr. Lee De Forest was an undergraduate student of Yale University. Following completion of his undergraduate work, he entered the Sheffield Scientific School of that university. In 1899, he received his doctorate, after the submission of his thesis, "Reflection of Hertzian Waves From the Ends of Parallel Wires." With his graduate work completed, he straightway entered the radio field, where his work would, in future years, have considerable effect upon the radio industry

[1] Clarke's equipment never gained favor.

[2] This firm was incorporated with a capital of $5 million, and was the parent organization of a group of operating companies, covering the entire Nation, total capitalization of which was planned to exceed $50 million.

[3] Frank Fayant, "The Wireless Telegraph Bubble," Success magazine, vol. X, No. 157, June 1907, p. 388.

[4] "Radioana," SRM 5–543, Massachusetts Institute of Technology, Cambridge, Mass.

of this country and still greater effect upon the electronics industry. Unfortunately, he was almost entirely devoid of business acumen and soon fell into the hands of unscrupulous associates, whose actions, to a large extent, nullified his efforts. Moreover, his own business ethics could be questioned, a fact which further nullified the effects of his work. In 1901, with $1,000 in capital, he formed a partnership with Mr. Edward Smythe and Prof. Clarence Freeman. De Forest and Smythe developed a responder to take the place of the coherer used by Marconi. Freeman produced a transmitter. In this same year they obtained a contract with the Publisher's Press Association to provide radio reports of the 1901 international yacht races. De Forest proceeded to New York and worked feverishly in preparing the equipment to report the races. While in the process of accomplishing this, he became acquainted with Col. John Firth who, in future years, was to exert great influence in American radio circles. Firth became quite interested in De Forest's activities and was able to interest four other promoters in investing $500 each, to form the Wireless Telegraph Co. of America, capitalized at $3,000. Freeman, Smythe, and De Forest were allotted $500 worth of stock in the company and applied for patents covering their equipment.

THE INTERNATIONAL YACHT RACES CREATE A RADIO FIASCO

In addition to the De Forest contract with the Publishers' Press Association for the reporting of international yacht races, Marconi was reporting for the Associated Press, as was another concern without sponsorship, the previously mentioned American Wireless Telephone & Telegraph Co. De Forest's contract provided for the payment of $800, if the results proved satisfactory. So unprepared was he for the competition that, had it not been for the long postponement of the races caused by the assassination of President McKinley, he would not have had his apparatus ready.

During the contest both the Marconi and De Forest mobile stations noticed their shore units signaling frantically with flags asking, "What is the matter? Signals confused. Cannot read." De Forest tried to improve his transmissions, and, seeing no more signaling, gained the impression he was getting through satisfactorily. When his tug docked he expected to be overwhelmed with congratulations, feeling he had made a great showing against his competitors. However, the event had produced three losers, Lipton's *Shamrock II*, Marconi, and De Forest. The American Wireless Telephone & Telegraph Co., having no sponsor, had nothing to lose and everything to gain by preventing the reception of their competitors' transmissions.[5] The simultaneous

[5] There is an account that the true culprit in this fiasco was American Wireless Telephone & Telegraph Co., which, upon failing in its efforts to get the press associations to make use of their apparatus in the 1901 yacht races, set up a very powerful station near the Navesink Highlands. Throughout the races they sent out so powerful a stream of electric disturbances that they produced the results previously noted in the Marconi and De Forest reception. Pickard maintains that the Gehring interests did report these races, saying "And when I say 'reported,' I mean reported and not what the Marconi and De Forest people call reporting; namely, manufactured news that had no basis of fact whatever." He stated that the Gehring group used a plain aerial, 20-inch Queens coil, and a tulip interrupter minus all weights, so that spark frequency was quite high. They put as much current in the primary as their interrupter would stand and, in so doing, radiated considerable energy, their damping coefficient being about 400. Their receiving station was located at Galilee and used aural reception as did De Forest. That, incidentally, gave them an advantage over Marconi with his coherer and inker. Pickard claimed that on the trip down to the race area a bright idea came to him as to the modus operandi to be employed to prevent Marconi and De Forest from receiving the transmissions. He happened to have a newspaper at hand, in which one page had been folded over in printing, so that a large-type headline was superimposed over the fine print of the text. He noted that the small type was almost unreadable but that the headline was undamaged. This gave birth to his idea. Why not use large type—namely long dashes many seconds in duration to smear the

broadband transmissions of the spark sets simply jumbled each other into both illegibility and incoherency.

The failures of the race-reporting efforts of the Marconi and De Forest interests proved of great value to others and, by experience, even to the losers. Shoemaker, who had developed the American Wireless Telephone & Telegraph Co. equipment, was catapulted into prominence in the radio world. The Navy, later, would find considerable use for his equipment.[6]

small-type ordinary dots and dashes of the competitors? Pickard proceeded to work up a code, which, he said, "was simplicity itself." As an example, one long dash of 10 seconds would mean *Columbia* was ahead; two such dashes would indicate *Shamrock* was in the lead; three, they were neck and neck. Following the first series would come other long dashes from one to nine, identified in the code as conveying common actions taking place. Thus equipped, they were able to get their signals through and interfere with the others. "Marconi and De Forest didn't have a ghost of a chance and our clever rewrite men made up a nice long story from our coded simple instructions." Strange as it may seem, they received instructions from Galilee sometime later to split time with Marconi, an order considered cowardly by Pickard. Contacting the *Mindora*, the Associated Press boat, with the Marconi so-called apparatus on board as Pickard put it, a liaison was arranged. In relating this incident, the professor tells of his encounter with the president of the Associated Press, "When some hundred feet away, none other than Melville Stone came on deck with a megaphone and began to berate us. For fully 10 minutes he cussed us, not repeating one word twice, and would probably be cussing us yet if I had not gone below, gotten an egg, and by a lucky throw applied it to him via his megaphone. Incidentally, he stopped cussing, and at the same time the negotiation stopped." In relating what he called "The final incident of the race 'reporting,' " Pickard said, "When the yachts crossed the finish line, we held down the key and then continued to hold it down, by the simple method of putting a weight on it. Thus, radiating waves, far from practically continuous, though continuous in our sense of the word, we sailed for our home port, and the batteries lasted for the entire hour and a quarter that we utilized to send the longest dash ever sent by wireless." Following the races, Pickard returned home via Navesink, where the lighthousekeeper showed him around and said, "Oh, by the way, we had wireless telegraphy here the other day. The Marconi men were here with a little black box like a stock ticker, and paper came out of it with long black lines running down the middle of it. Every few minutes the operator would pick up this tape, look at a few feet of it, swear unholily, tear the tape off, and jump on it." Of this Pickard stated, "This was the best appreciation of efforts that I ever received." "Radioana," op. cit., SRM 5–543).

THE NAVY'S POSITION, 1901

The Navy's position during this period is best described in the 1901 Annual Report of the Secretary of the Navy:

At the request of the Bureau, the Department in April last ordered a board for the purpose of considering and reporting upon the advisability of discontinuing the homing-pigeon service used for the transmission of messages from distant points and substituting in lieu thereof some system of wireless telegraphy. After various changes in its membership the board reported in May to the effect that the homing-pigeon service should be discontinued as soon as some system of wireless telegraphy is adopted. In the opinion of the Bureau the pigeon service should be discontinued at once, since it does not appear to be of any practical use at present, nor has it in the past developed any great promise of success in naval operations.

The board above mentioned did not in its researches include any practical tests of the various systems of wireless telegraphy used in this country. The Bureau has taken the matter up and investigations are now in progress with a view of carefully ascertaining the exact condition of the many systems of wireless telegraphy more or less used or recommended.

An officer of the Bureau recently witnessed the efforts of various press companies to report by means of wireless telegraphy the progress of the international yacht races. The systems in use for that purpose were those of the Marconi Company, the American Wireless Telegraph Company (De Forest system), and the American Wireless Telegraph and Telephone Company. It was clearly shown during the races that the difficulties of "interference" could not be overcome with the apparatus used by the above-mentioned companies. When there was no interference, however, generally speaking, the appliances of all companies worked successfully.

The Secretary's report went on to note that the Marconi apparatus had been improved considerably over the past year,

[6] "Radioana," op. cit., SRM 5–737, p. 2 (Col. John Firth, "The Story of My Life," unpub. mss., n.d.).

but that while claims had been made that the difficulty of "interference" could be overcome, the Bureau was not aware of any positive exhibition or demonstration of this. One of the practical improvements reported was the grounding of the antenna circuit through the primary of an induction coil. The report also mentioned that communications had been successfully conducted between British warships, up to a distance of 160 miles.

It was observed that the New York Herald had installed Marconi equipment on board the Government lightship anchored off New South Shoals, for the purpose of reporting arrivals of transatlantic steamers. Near the village of Seasconset on Nantucket Island, a smaller installation had been established to relay the messages received from the lightship. With several of the major transatlantic steamers having installed Marconi sets, that system was attracting the attention of the commercial world. Lloyds, failing in attempts to develop a practical system of its own, found Marconi equipment best suited for its needs and had contracted for its use.

Continuing, it stated:

> Most of the principal naval powers have adopted some form of wireless telegraphy for their ships. Great Britain and Italy use the Marconi system; Germany the Slaby system, and France and Russia the Ducretet system. It is believed, however, from the reports received, that none are satisfactory.
>
> Claims of superiority are made for certain features adopted by some of the American wireless companies. For example, the De Forest system includes the use of a motor generator for transmission, by the aid of which it is expected to obtain a mechanical tuning between the sending and receiving stations and thus avoid interference. It is not believed that this mechanism has passed beyond the experimental stage. Experiments in the same field, for the same purpose are being conducted by Mr. Nikola Tesla, and the results are awaited with much interest.

In conclusion, the Bureau did not deem it advisable to adopt any particular system at the time or to acquire any more radio apparatus than was needed for purposes of instruction. It was obvious that no system had advanced beyond the experimental stage.

REAPPRAISAL AND STUDY OF THE SITUATION

Sometime during the fall of 1901, the Navy Department reached a decision to study the situation and, if results warranted it, to conduct tests of available equipment.[7] It did not appear that any American firm had succeeded in the development of apparatus fitted to the Navy's needs. There seemed to be few basic improvements in Marconi's equipment and, moreover, his firms held steadfast to their leasing policy. These factors made it necessary that a study of the apparatus of other European manufacturers be conducted, and Comdr. Francis Morgan Barber, USN (retired),[8] then residing in Paris, was called to active duty on 1 October 1901, for the purpose of studying and making a report on European radiotelegraph apparatus and methods of operating.[9]

Following the issuance of the orders to Barber, questions arose as to the propriety of ordering him to this assignment, it being

[7] Letter, dated 9 Dec. 1901, Chief of the Bureau of Equipment to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.; memorandum, dated 4 Jan. 1902, Chief of the Bureau of Equipment to the Chief of the Bureau of Construction and Repair, files, Bureau of Equipment, National Archives, Washington, D.C.; Letter, dated 27 Jan. 1902, Chief of the Bureau of Equipment to Commandant, Navy Yard, Washington, D.C., files, Bureau of Equipment, National Archives, Washington, D.C.

[8] Francis Morgan Barber was born in Pennsylvania, appointed to U.S. Naval Academy from Ohio, graduated in 1865. He was a classmate of Bradford. In 1895, he was retired at his own request because of poor health. Following retirement he took up residence abroad. Fluent in French and German, and with a good command of other languages, he had served as naval attaché to various countries and was acquainted with many top government officials of those countries. He was independently wealthy, extremely well poised, dignified, and learned in many ways. At the time of his recall to duty he was living quietly in Paris and was about 55 years of age. Following his release from active duty he was promoted to the rank of captain on the retired list. He died in New York City on 30 Jan. 1922.

[9] Letter, dated 1 Oct. 1901, the Secretary of the Navy to Comdr. Francis M. Barber, USN (retired), files, Bureau of Equipment, National Archives, Washington, D.C.

possible that it was not in accordance with the spirit of the reciprocity arrangement governing information exchanged with foreign countries. The Office of Naval Intelligence considered that the U.S. naval attaches could better pursue the matter, and that such activities were one of their functions. It was further opined that the detailing of another officer to conduct such work would diminish the influence of the naval attaches in the countries to which they were accredited. It was stressed that the acquirement of knowledge of radiotelegraphy by officers on the active list would be of greater value to the service than by a retired officer.[10] Despite the objections, the nominee of the Bureau of Equipment was deemed to have the best qualifications for the duty and, morever, could devote his full and undivided attention to the project. Secretary of the Navy John D. Long adhered to his original decision and requested the State Department to issue Barber a special passport [11] to permit him to travel in connection with radio investigations and to provide him with a letter of introduction to the diplomatic and consular officers of the United States throughout Europe.[12]

Barber assumed his duty with zeal and efficiency, but in spite of his enthusiasm he encountered numerous obstacles. Misunderstanding concerning the nature and scope of his mission often resulted in a lack of cooperation by U.S. officials abroad.[13]

In his first reports dated 4 and 6 December 1901, he outlined the existing state of radiotelegraphy in Europe. He stated that all the continental navies maintained a high degree of secrecy concerning the results of their experiments and in his opinion it was a lack of definite accomplishments, rather than successes, which they were attempting to hide from each other. He felt that for maritime purposes radio was invaluable, in spite of its defects, and he believed the U.S. Navy was the only one in the world that was not hard at work on it. He recommended that the Navy should cease wasting time in determining which apparatus to purchase. In carrying out his recommendation he suggested the Navy Department should:

Obtain a special appropriation from Congress for the investigation of equipment;

Appoint a board of officers on the active list for a study of equipment;

Establish two experimental stations—one between Newport and Montauk and the other between Key West and Tortugas in order that the behavior of the electrical waves where there is a change of seasons may be compared with their behavior where there is always warm weather so that when a vessel fits out at New York it will be already known what adjustments or additions are necessary to hear wireless telegraphic apparatus if she is to go into the tropics. Hot weather does make a difference, and,

Buy two complete sets of apparatus from Marconi, Ducretet-Popoff, Rochefort, Slaby-Arco and Braun-Siemens and such other instruments as the Naval Attachés or myself may from time to time discover and recommend. These purchases will doubtless represent the very best that the foreign navies are using for the reason that each manufacturer will know that he is practically going into competition and being protected by patents he can hope to win a large order for a part or all of his kind of instrument. But he can only hope to win if he furnishes what he knows is the very best and that is certain to be similar in effect to what the Navy of his country is using. I doubt if any nation has the necessary plant at its navy-yards or elsewhere to make its own electrical apparatus unless it be some small matter involving a cipher code which is not what we are after anyway. A practical business connection being thus formed with all these manufacturers, I think there will be little difficulty in keeping touch.[14]

[10] Memorandum, dated 7 Mar. 1902, Office of Naval Intelligence to the Chief of the Bureau of Navigation, files, Bureau of Equipment, National Archives, Washington, D.C.

[11] Letter, dated 29 Oct. 1901, the Secretary of State to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[12] Letter, dated 4 Nov. 1901, the Secretary of the Navy to Comdr. F. M. Barber, USN (retired), files, Bureau of Equipment, National Archives, Washington, D.C.

[13] Letters, dated 10 Jan., 17 June, 20 June, and 11 July 1902; Comdr. F. M. Barber USN (retired), to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[14] Letters, dated 4 and 6 Dec. 1901, Comdr. F. M. Barber, USN (retired), to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

PURCHASE OF EUROPEAN EQUIPMENT FOR TESTS

Based upon his studies, investigations, and recommendation the Navy Department decided to purchase, for the purpose of conducting comparative tests, two sets each, from four European companies: Slaby-Arco, Braun-Siemens-Halske, Ducretet, and Rochefort. The first two were German companies; the last two, French. In January 1902 he was authorized to arrange terms for the purchase of the above sets, complete with spare parts.[15] Allgemeine Elektricitats-Gesellschaft (Slaby-Arco) quoted prices on its types A, B, and C sets at M5,000, M6,000, and M7,000, respectively.[16] The type A was guaranteed for sea distances up to 31 miles. Type B, which was in use by the German Navy, was guaranteed for distances up to 62 nautical miles, while type C was guaranteed for 74 nautical miles.[17] The Bureau had specifically instructed Barber that "it is desired to duplicate, as nearly as possible, the apparatus usually supplied German warships." [18]

During the course of the negotiations, the Slaby-Arco firm attempted to increase the price of the type B sets from M6,000 to M7,000 and, in addition, endeavored to make it a condition of the sale that the Navy bear the trip and per diem expenses of two of its men to the United States in lieu of one, as originally planned.[19] This, according to the firm's manager, was for the purpose of insuring the complete success of the installations. Informing the Chief of the Bureau of Equipment of this, Barber commented, "The amount of information that can be gathered from experts like that on the ground cannot be overestimated," but he added that the practical thing to do was to demand that the firm stick to its original price, and that the Navy offer to pay only the expense of one engineer.[20]

The Bureau's reply to Barber was emphatic,

> Please inform the Allegemeine Elektricitats-Gesellschaft that the Bureau expects the fulfillment of its orders as originally placed and at the prices quoted when the orders were placed. If they are not prepared to do this the Bureau will consider their letter to you of April 2, 1902, as a cancellation by them of this contract.[21]

Faced with the possibility of the cancellation of their contract, the company quickly acceded to the Navy's demands and, as further assurance, provided their engineers without charge.

While negotiating with Ducretet for the purchase of two sets of his equipment, for which the Navy paid $2,614.37, Barber asked him, "In case the services of an expert are required to proceed to the United States and install the apparatus, what would be the total cost of his employment?" M. Ducretet replied, in his conditions regarding the sales of his apparatus, "It will suffice to your Government to send me one or two intelligent men. They will be instructed in these apparati for wireless telegraphy in our laboratory—that will suffice. Many governments have already done this." [22]

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[15] Letter, dated 13 Jan. 1902, Chief of the Bureau of Equipment to Comdr. F. M. Barber, USN (retired), files, Bureau of Equipment, National Archives, Washington, D.C.

[16] At this time the German mark was equivalent to $0.238.

[17] Specifications, dated 16 Jan. 1902, the Allegemeine Elektricitats-Gesellschaft, Berlin, on various types of radio apparatus.

[18] Letter, dated 11 Mar. 1902, Chief of the Bureau of Equipment to Comdr. F. M. Barber, USN (retired), files, Bureau of Equipment, National Archives, Washington, D.C.

[19] Letters, dated 3 and 6 Apr. 1902, Comdr. F. M. Barber, USN (retired), to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[20] Letter, dated 3 Apr. 1902, Comdr. F. M. Barber, USN (retired), to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[21] Letter, dated 19 Apr. 1902, the Chief of the Bureau of Equipment to Comdr. F. M. Barber, USN (retired), files, Bureau of Equipment, National Archives, Washington, D.C.

[22] Letter, n.d., E. Ducretet to Comdr. F. M. Barber, USN (retired), files, Bureau of Equipment, National Archives, Washington, D.C.

Two sets were purchased each from Braun-Siemens-Halske and Rochefort for $3,470.04 and $2,285.30, respectively.[23]

Following the decision to purchase eight sets of European radio equipment, the Chief of the Bureau of Equipment took steps to carry out the third of Barber's recommendations.[24] While the fleet was adequately supplied with signalmen well versed in wigwag and in the operation of Ardois night lights, and with able electricians, the problems involved in the care and operation of radio equipment were more complicated. Admiral Bradford informed the Secretary of the Navy in February 1902 that it would be necessary to employ at each station a competent person to act as operator and instructor, who should be an educated electrician, skilled in the care and adjustment of delicate electrical apparatus.[25] Since there were no stations or laboratories in this country where persons could be instructed in the special care and adjustment of the sets of the particular types of apparatus the Navy was purchasing, it was suggested that a team consisting of one officer, not above the rank of lieutenant, and two enlisted men be sent abroad for instruction in the care and adjustment of the sets. He brought out that this was the practice followed by foreign governments. The two enlisted men would ultimately be ordered in charge of the test stations to be established at the Washington Navy Yard and at the U.S. Naval Academy, Annapolis, Md. It was also suggested that a special rating be created for radio operators, and that this rating be granted only after careful training and demonstration of competence at one of the testing stations.[26]

BASIC TRAINING OF NAVAL PERSONNEL IN MAINTENANCE AND OPERATIONS OF EUROPEAN EQUIPMENT

The Secretary approved the recommendations of the Bureau Chief. Lt. J. M. Hudgins, USN,[27] and two chief electrician's mates, James H. Bell and William C. Bean,[28] were ordered to Paris to report to Barber for duty, in connection with witnessing tests of wireless telegraph apparatus, and for making detailed study of this apparatus, especially the four systems which had been purchased by the Navy Department for competitive tests.[29] The know-

[23] Letters, dated 30 Jan., 14 Mar., 19 Mar., and 14 Apr., 1902, F. M. Barber, USN (retired), to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.; letters, dated 3 and 17 Feb. 1902, Chief of the Bureau of Equipment to the Chief of the Bureau of Supplies and Accounts, files, Bureau of Equipment, National Archives, Washington, D.C.

[24] Supra, p. 41.

[25] Letter, dated 12 Feb. 1902, Chief of the Bureau of Equipment to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[26] Letter, dated 15 Mar. 1902, Chief of the Bureau of Equipment to the Secretary of the Navy; memorandum dated 15 Mar. 1902, Chief of the Bureau of Equipment to Chief of the Bureau of Navigation, files, Bureau of Equipment, National Archives, Washington, D.C.

[27] J. M. Hudgins was born in and appointed a naval cadet from Virginia. He graduated from the U.S. Naval Academy in 1894. His knowledge of engineering and experience made him a logical choice for the mission. Not only was he a well-informed engineering officer, but in addition he had received post-graduate engineering instruction in Paris, and while there had gone through the Ducretet plant. His contributions to the progress of naval radio were outstanding, one of them being his compilation of the Navy's first instruction book in this field. He became the head of the Radio Division, Bureau of Equipment in 1904. The Navy suffered a great loss in his untimely death, the result of a turret explosion in the U.S.S. *Kearsarge*, which occurred during target practice off Guantanamo Bay, Cuba.

[28] James H. Bell and William C. Bean were selected for this duty after a careful study of the records of all chief electrician's mates, as best qualified to quickly assimilate knowledge and possessing the capability to instruct others. These two men became the backbone of the training program and had much to do with the development of naval radio. Both men retired with the rank of lieutenant.

[29] Letter, dated 7 Aug. 1902, Lt. J. M. Hudgins, USN, to Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

ledge and experience so gained was to prove of great value in installing the apparatus for testing purposes and in instructing Navy personnel in its use, care, and maintenance.[30]

On 2 May 1901, Hudgins and his two students sailed for Europe on the SS *Fuerst Bismarck* and arrived on 9 May, in Paris where Barber took the trio in charge. Barber's functions at this stage were mostly of a diplomatic nature. Hudgins was the engineering head of the group. The first months the men devoted their time to studies of the Rochefort and Ducretet equipments. Hudgins was occupied in obtaining information concerning other French makes of radio apparatus and its use in the French Navy. In this quest he was handicapped by "In Defence Nationale." All the data he obtained relative to its military use was necessarily gleaned from outside sources.[31] The French Government, at that time, exercised strict control over all individuals engaged in long-distance radio experiments.[32] This was quite a contrast to the situation then existing in the United States, where our Government found itself unable to prevent the establishment of foreign-controlled stations.

On the advice of Barber, Hudgins left his two assistants studying under Messrs. Rochefort and Ducretet, while he witnessed tests being carried out by M. Popp, president of the Compagnie General Telegraphie et Telephonie Sans Fil, between two stations, one of which was on the steam yacht *Lysistrata,* owned by Mr. James Gordon Bennett, who had made it available to the U.S. Navy to conduct experiments with new Branly apparatus.[33] The other station, first located on shore, was later transferred to USS *Nashville,* then at Villefranche. These tests were to compare Professor Branly's new "tres-piede" detector with the coherer in order to determine which was the superior. With a Ducretet set at one station, first ashore, and then on *Nashville,* and a Rochefort on the *Lysistrata,* the new Branly device was used as an alternative detector at either end. The information gathered from these tests was negative in character, with numerous mishaps disclosing the extreme care necessary in installing and operating the equipment, and the unfitness of the "tres-piede" detector for use on board ship or other unsteady platforms.[34]

The team moved to Berlin on 7 June and began studies of the Braun-Siemens-Halske and the Slaby-Arco equipments. The Slaby-Arco Co. had three outlying receiving stations in addition to the transmitting unit at the plant, and it was with these that the Navy team received its introduction to effective German wireless. Entering upon an intensive study of the Slaby-Arco transmitter and receiver, they gained a complete knowledge of the mechanical construction and a thorough insight into the adjustment of receiver, coherer, and relay. From copying nearby German Army stations, which used Slaby-Arco equipment, as did also the German Navy, they developed "coherer technique." They concluded there was little difference between the German sets, which they considered superior in design and construction to the French.[35]

[30] Annual Report of the Secretary of the Navy, 1902, p. 375.

[31] Letter, dated 7 Aug. 1902, Lt. John M. Hudgins, USN, to Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[32] Letter, dated 28 Feb. 1902, Comdr. F. M. Barber, USN (retired), to the Chief of the Bureau of Equipment; Letter, dated 13 Jan. 1902, the Chief of the Bureau of Equipment to Commander Barber, files, Bureau of Equipment, National Archives, Washington, D.C.

[33] Letter, dated 25 Apr. 1902, Comdr. F. M. Barber, USN (retired), to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[34] Letter, dated 7 Aug. 1902, Lt. J. M. Hudgins, USN, to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[35] Letter, dated 7 Aug. 1902, Lt. J. M. Hudgins, USN, to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

Hudgins found the German naval personnel far more cooperative than the French and reported,

> . . . I wish to refer to the courtesy of the German Navy Department in granting me permission to inspect the station on board the German man-of-war *Neptun* at Kiel, and also the courtesy of the officers of the *Neptun* in explaining fully the working of wireless telegraph apparatus in the German Navy.[36]

From Germany the trio moved to England, where it spent the period 6 through 16 July examining Marconi devices manufactured at Chelmsford and the installations there, and at Frinton-on-Sea, and at North Forelands. At the Marconi Chelmsford factory they were restricted in their observations, being shown only the masts and the outsides of the buildings. They were not permitted to see the Poldhu station, it being explained to them that the British Admiralty had issued such orders. In reference to this visit Bean said, "The Marconi people didn't seem to want to let us see anything," and "They seemed to feel that we were spying." [37] They obtained data from other manufacturers and experimenters, including the Lodge-Muirhead firm at Elms in Kent, where they were treated courteously and were willingly shown apparatus developed by Sir Oliver Lodge and Dr. Muirhead, of London. The principal novelty of the Lodge-Muirhead equipment was a coherer consisting of a very thin, clockwork-driven disk of hard steel, about one-half inch in diameter, revolving in contact with mercury. Hudgins purchased one of these detectors and brought it back to this country. The products of the Hozier Braun people and Mr. H. W. Sullivan were also inspected. Sullivan, at that time, was manufacturing radio apparatus for the Admiralty, based upon designs of Captain Jackson, Royal Navy. This equipment closely resembled that made by the British Marconi Co.[38]

COMMENTS AND RECOMMENDATIONS CONCERNING EUROPEAN EQUIPMENTS

On 7 August 1902, Hudgins submitted the final report of his trip to the Chief of the Bureau of Equipment. In this he listed, in order of merit and adaptability to naval service: Marconi, Braun-Siemens-Halske, Slaby-Arco, Rochefort, and Ducretet.[39] He attributed superiority of the Marconi installations over the German makes as being due to the greater skill and experience of the engineers in installing and operating the apparatus itself and the use of better tuning devices.[40]

He went on to note that the Braun sets could be tuned much sharper than the Slaby-Arco and Marconi, but the frequency could not be easily changed in either the transmitter or the receiver. The Slaby-Arco

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[36] Ibid.

[37] "Radioana," SRM 100–232, SRM 4–547, p. 4, Massachusetts Institute of Technology, Cambridge, Mass.

[38] Letter, dated 7 Aug. 1902, Lt. John M. Hudgins, USN, to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[39] In later comments on this preferential list, James H. Bell stated: "It may be said . . . that the British Marconi Co. lost its great chance when it refused to sell twenty sets to the United States Navy. Had these been received, workable as they undeniably were, they would have had the advantage of priority, and this is always of great value. The hold which the German wireless interests obtained in the supply of wireless apparatus to the United States Navy, as a direct result of the selection of the Slaby-Arco by the Washington official tests, persisted for almost a decade. Had two sets of Marconi apparatus been included in the purchase of sets by the United States Navy abroad in 1901, Marconi might have won over Slaby-Arco. My own knowledge of the sets of that date would lead me to say that the race would have been a close one, with Marconi a very close second though not clearly and evidently the winner. However, they had their chance under proprietary order a year before, and with twenty sets in Navy use it would have been hard, at least for a foreign manufacturer to have come into too active competition with them" ("Radioana," SRM 100–222, 230, p. 1, Massachusetts Institute of Technology, Cambridge, Mass.).

[40] Letter, dated 7 Aug. 1902, Lt. John M. Hudgins, USN, to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

equipment was superior to the Braun for distance. Neither of the French systems were tunable. He felt that, while some of the apparatus was good in design, it appeared rather clumsy, as did most of the devices inspected. In discussing this matter later, Hudgins was of the opinion that the French, in trying to give their equipment an artistic appearance, had succeeded only in making it look fantastic, while the Germans, who stressed efficient design and fine mechanical construction, failed in the artistic touch. The Americans favored a combination of the French flair for the esthetic with the skill of German engineering.[41]

In all the installations and tests witnessed abroad, Hudgins was forced to the conclusion that the published reports on European radiotelegraph apparatus were willfully misleading, with no experimenter publishing anything but his best results. He found no apparatus which worked in an entirely satisfactory manner, there being always interference, lack of adjustment, or some fault either in the transmitter or receiver which rendered accurate reception of a message difficult or doubtful. Four or five repetitions of transmissions were not unusual.[42]

[41] Ibid.

[42] Ibid. At this time European press utterances by rival manufacturers of wireless telegraphic apparatus were common occurrences. Marconi maintained that his German competitor Slaby-Arco simply copied his method and actually turned out a Germanized Marconi system. The German firm indignantly denied this. To add to the turmoil, Dr. Braun insisted hotly, at regular intervals, that he was the man to whom success of radio communications was due. Siemens and Halske, manufacturers of his apparatus, were of the same opinion. They instituted action against the Allgemeine Elektricitats Gesellschaft, the owners of the Slaby-Arco patents, and were also preparing to start proceeding against the English Marconi Co. Until this time, the little opera bouffe war found expression chiefly in the refusal of the rival companies to receive one another's messages when sent from ships or shore stations (Scientific American, 19 Apr. 1902 (Munn & Co. New York), p. 275)).

FURTHER CONTROVERSY WITH MARCONI INTERESTS

While Hudgins was visiting their plant in England, the disagreement between the Marconi interests and the U.S. Navy flared anew. This developed in connection with statements attributed to Barber and published in the New York Herald of 18 June 1902:

> There will be no tests of the Marconi system because we have been unable to make terms with the Company. They demand a royalty of $500 a year for every instrument while other companies make no excessive demands. It is not improbable that wireless communication may form the basis of an international trust. There is a company now forming, the purpose of which, I am told, is to obtain rights to erect stations and conduct wireless telegraphy on a commercial basis. As for the claim that Mr. Marconi or any other inventor can demand exclusive privileges through patent rights, I do not believe any monoply can be secured by infringement suits or similar procedure.

Three days later the Marconi Wireless Telegraph Co. of America wrote Barber calling him to task for his statements. The closing paragraph of this letter asked him to make amends:

> We trust, therefore, that in justice to this Company you will, in case you have been misrepresented, deny the accuracy of the interview, demand that the statement you made, if any, be correctly published in the New York Herald and its Paris edition, and protest against being made, as you have undoubtedly been made, the medium of interested attacks upon the Marconi system.[43]

In a letter to the Editor of the Herald, which appeared in its 21 June issue, the Marconi Wireless Telegraph Co. of America stated that Barber was "imperfectly and curiously informed," as, under date of 22 May, Admiral Bradford, in charge of such experiments, had specifically invited the Marconi Co. of America to participate in this trial, stating, "The Bureau would be

[43] Letter, dated 5 July 1902, Cmdr. F. M. Barber, USN (retired), to Chief of the Bureau of Equipment; ltr., dated 21 June 1902, from Executive Committee, Marconi Wireless Telegraph Co. of America, to Commander Barber, files, Bureau of Equipment, National Archives, Washington, D.C.

pleased to have sets of your apparatus submitted for test." It then went on to attack Barber's purported statement, asking in what respect he believed that sustained patents on wireless telegraphy differed from patents in telephony, or type-setting, or any other field of industry? It maintained that Marconi held the basic patents and that his priorities were beyond question, and that, if the owners of the "so-called Slaby-Arco and Braun systems" offered the opportunity, they would be sued for infringement. They closed with "Why, may we ask, should Marconi be defrauded of his rights?" [44]

Barber, in reply, said he had been misquoted, his statement being that he had indicated that he had not been ordered to buy any Marconi apparatus since the Bureau was dealing directly with the Marconi Co. Referring to the question of patents he said, he did not specify Marconi patents as being worthless, but rather that he thought wireless telegraphy patents were only good when they pertained to specific apparatus for producing certain results and that "Wireless Telegraphy as a whole system was unpatentable—Every child knows this." [45]

The Chief of the Bureau of Equipment did, as stated, invite the Marconi Wireless Telegraph Co. of America to participate in the forthcoming comparative tests. In July the Marconi Wireless Telegraph Co. of America informed him that two complete wireless sets were ready for delivery to the Navy, for tests between two vessels or land stations, but expressed regrets that the Company could not comply with the Bureau's wishes of selling them outright for the purposes of the proposed competitive tests, nor could they quote the cost of 10 or more of its units prior to completion of the tests.[46]

The Secretary of the Navy's annual report for the fiscal year 1902 contains the following comment:

The Bureau regrets that it has been unable to reach any satisfactory agreement with the Marconi Wireless Telegraph Co., for the purchase of its appliances should it be desired after testing same. The Company has offered a duplicate set for test to be returned after the trials have been completed. This Company requires, however, the payment of a given sum for each set upon delivery and a royalty for each year during the life of the patent. The aggregate cost of a set under such an agreement would be very great. In addition, it is illegal to obligate the payment of money beyond a single fiscal year. The Bureau regrets that it has been unable to reach a satisfactory basis for the possible acquisition of appliances which have such a good reputation as those of the Marconi Wireless Telegraph Co. It appears from this letter that the Marconi Wireless Telegraph Co., of America, which the Bureau is reliably informed is controlled in London, objects to the Department acquiring other wireless telegraph appliances than its own, and yet refuses to supply the latter except under terms which are illegal and of great disadvantage to the Government.[47]

TESTS OF AMERICAN MANUFACTURED EQUIPMENT

The Wireless Telegraph Co. of America, which had been organized in 1901 to exploit the developments of De Forest, was short lived. Firth, one of the original stockholders of this company, innocently interested a very personable and extraordinarily lucky stock promoter, Schwartz, alias Abraham White, in the De Forest system. This unscrupulous gambler, with his magnetic enthusiasm, was to exert a profound and unfortunate effect upon the future of the young scientist and upon the development

[44] Letter, dated 19 June 1902, Marconi Wireless Telegraph Co. of America to the editor of the New York Herald.

[45] Letter, dated 5 July 1902, Comdr. F. M. Barber USN (retired), to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[46] Letter, dated 3 July 1902, Mr. J. Bottomley, general manager, Marconi Wireless Telegraph Co. of America, to Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[47] Annual Report of the Secretary of the Navy for 1902, p. 376.

of the radio industry. By February 1902, White had organized the De Forest Wireless Telegraph Co., incorporated in Maine with a capitalization of $3 million,[48] the nucleus of which was the original De Forest firm. Freeman and Smythe were not included in this new organization. Freeman's "sending apparatus" did not amount to much, said De Forest, and, as for the "responder," he felt it was more his invention than Smythe's,[49] As vice president and scientific director of the new corporation, De Forest received a sizable block of stock and a salary of $20 a week, "more than he had ever earned before." [50] De Forest became hypnotized by White's dreams of "worldwide wireless", and the rosy picture he painted of the potentialities of the medium.[51]

Far from being an entrepreneur in the true sense, White's ideas were exactly the same as those of promoter Gehring; to sell as much stock as possible to the public, regardless of its value, and to reap the maximum personal benefit. White had a moneymaking instinct and the ambition to make a fortune. The success of the Gehring organization in selling large issues of their radio stock convinced him that a $3 million company was too small, so, emulating Gehring, White formed the $15 million American De Forest Co. The new company did not absorb the old one. White simply rented it for $500 per annum, thereby rendering its stock worthless.[52] De Forest was also a vice president and the scientific director of this new company, and received a sizable, nonnegotiable block of stock. He was sincere in his efforts and endeavored to improve the equipment and had no connection with the stock-promotion enterprise. The Navy, in the middle of 1902, contracted with the American De Forest Co. for two sets of equipment for comparative testing. These were delivered in December of that year.

In 1902, two honest Pittsburgh entrepreneurs, Messrs. Hay Walker and Thomas Given, established the National Electric Signaling Co. This firm was formed to support the work of the irascible Prof. Reginald Fessenden, who, with original ideas, had made considerable progress in the development of radio equipment while in the employ of the U.S. Weather Bureau. Walker and Given were not interested in the manufacture or sale of radio equipment nor in establishing a communication network, but hoped to develop a system which could be sold as a package to an operating company.[53] On 16 August 1902, the Bureau of Equipment requested bids for two sets of equipment from Queen & Co., Philadelphia, Pa., a firm which was purported to be the manufacturer of Fessenden apparatus. Four days later they replied they would provide prices, guarantees, and dates of delivery within a few days. They failed to follow this letter with further action.[54]

The Consolidated Wireless Co., whose engineer, Shoemaker, had developed the equipment which had so successfully interfered with the reception of the Marconi and De Forest transmissions during the 1901 international yacht races, was provided with a contract for two receivers. For reasons unknown, they did not desire to provide transmitters.

Nikola Tesla, who claimed his apparatus was equal to and perhaps superior to Marconi's,[55] was also asked to submit prices for two sets, but he did not do so.

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[48] Samuel Lubell, "Magnificent Failure", Saturday Evening Post (Curtis Publishing Co., Philadelphia, Pa.), 17 Jan. 1942, p. 21.

[49] Fayant, op. cit., p. 388.

[50] Lubell, op. cit., p. 21.

[51] Ibid.

[52] Fayant, op. cit., p. 450. One of De Forest's original associates in the Wireless Telegraph Co. of America asked for the appointment of a receiver for the American De Forest Co. This was finally settled out of court.

[53] W. Rupert Maclauren, "Invention and Innovation in the Radio Industry" (Macmillan Co., New York, 1949), pp. 63–67.

[54] Infra, p. 120.

[55] Electrical World and Engineer (McGraw-Hill Co., New York), vol. 37, No. I, 1901, p. 48.

There were other reliable firms started during 1902, but they were small and lacked sufficient publicity to bring them to the attention of the Bureau of Equipment. Two of these, which would later provide good equipment to the Navy, were the Stone Telephone & Telegraph Co., Boston, Mass. and the Massie Wireless Telegraph Co., Providence, R. I.

SUMMARY

Due to the efforts of the Chief of the Bureau of Equipment, twelve radio equipments of 6 different manufacturers, 4 European and 2 American, were ready for comparative tests prior to the end of 1902.[56]

[56] Later, on 30 Mar. 1903, two sets of equipment were ordered from the Lodge-Muirhead Co. of England.

CHAPTER V

Early Planning and Development Problems

PREPARATION

While Barber and Bradford were procuring equipment, the Navy was engaged with plans to prepare personnel, ships, stations, and schools to meet the problems involved in testing, installing, and operating radio equipment. These plans included the establishment of two radio stations, one at the Washington Navy Yard, the other at the U.S. Naval Academy, Annapolis, Md.,[1] for the purpose of conducting comparative tests of the equipment being purchased. The extent of these preparations are detailed in Bradford's letter, dated 27 January 1902, to the Commandant, Navy Yard, Washington. This included instructions as to the method of installing the necessary "earth" at the stations, which, ". . . must be carefully done to insure long-distance transmission . . ." It was recommended that several large copper sheets having, in the aggregate, about 125 square feet of surface, on one side, be buried, horizontally, at least 6 feet below the surface, or deeper if in sandy or dry soil. These earth plates were to be put as near as possible to the place where the instruments were to be installed, but not necessarily near the antenna masts. They were to be connected by several large, uninsulated, copper, electric-light wires by carefully soldering them to clean, dry surfaces of the plates, and finally these wires were to be brought to the surface and in turn soldered to a single copper strip placed conveniently near the point where the instruments would be located. The last-mentioned copper strip would serve for making all ground connections of the apparatus.[2]

Instructions were issued to prepare ships' masts to accommodate antennas. In a memorandum to the Bureau of Construction and Repair, dated 4 January 1902, the Bureau of Equipment requested that "all ships under construction except the four single-turret monitors, and those to be built in the future, be provided with masts suitable for the use of radiotelegraph apparatus." [3] On battleships and cruisers, it suggested the use of hemp rigging for the topgallant mast and the insulation of the topmast wire rigging from the ship by setting up with hemp lanyards. It was further suggested that the lower masts be of steel while topmasts and topgallant masts be of wood. Unfortunately, no decision was reached at this time relative to the locations of the transmitters and receivers, nor was a belowdeck installation specified.

Taking steps to obtain the most desirable locations for shore radio stations, the Bureau of Equipment, in May 1902, recommended that the Secretary of the Treasury be asked to permit the Navy Department to erect a mast and small operating build-

[1] Letter, dated 9 Dec. 1901, Chief of the Bureau of Equipment to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[2] Letter, dated 27 Jan. 1902, Chief of the Bureau of Equipment to Commandant, Navy Yard, Washington, D.C., files, Bureau of Equipment, National Archives, Washington, D.C.

[3] Memorandum, dated 4 Jan. 1902, Chief of the Bureau of Equipment to Chief of the Bureau of Construction and Repair, files, Bureau of Equipment, National Archives, Washington, D.C.

ings at the following lighthouse stations: Cape Cod, Mass.; Montauk Point, Long Island; Highlands of Navesink, N.J.; Cape Henry, Va.; and Golden Gate (Bonita), Calif. These stations were to communicate, respectively, with the Boston Navy Yard; the Torpedo Station, Newport, R.I.; New York Navy Yard; Norfolk Navy Yard; and Mare Island Navy Yard and the Yerba Buena Training Station, San Francisco. The stations thus established would, at a later time, be used to communicate with the naval vessels to be fitted with radio installations.[4]

This request was approved by the Secretary of the Treasury in a letter of 4 June of that year,[5] with the following reservations:

> That the masts and other appliances be established and maintained at the Light Stations without cost to the Treasury Department and erected at such points on the Light Station sites as the Lighthouse Establishment designated.
>
> That Navy personnel connected with the erection and maintenance of the wireless installation at Light Stations not interfere with employees at the Light Stations and that they be subordinate to and under the supervision of the Principal Lightkeeper at each Light Station.
>
> That the masts and wireless equipment be removed from the Light Stations by the Navy Department whenever requested by the Treasury Department in the interest of the Lighthouse Establishment.

With the envisioned establishment of quite a few stations and the consequent requirement for operators, plans were made for setting up school units at Newport, New York, and San Francisco for the instruction of personnel in operating and maintenance. The Bureau of Navigation was tardy in implementing these plans, and when, in 1903, they detailed 13 students to the school at the Brooklyn Navy Yard, the number was far less than the existing requirement. This caused a temporary decline in the rate of progress of the installation program.

Plans were also formulated for installing apparatus at Key West and Dry Tortugas, Fla., as had been recommended by Barber, for the purpose of studying the effects of varying climatic conditions on radio equipment and transmissions. These plans were not put to use.

THE COMPARATIVE TESTS

The eight sets of European equipment arrived about the 1st of August 1902. At the request of the Bureau of Equipment, a board was appointed by the Secretary of the Navy to supervise the trials and determine the type of apparatus best suited to the needs of the Navy. The Bureau was handicapped by lack of officers adequately trained in radio, and those who had the necessary qualifications had other primary duties and could not devote their full time to the work. This proved true of the five-member Wireless Telegraph Board, which was appointed on 14 August 1902, and which convened 4 days later. It was composed of Comdr. Conway H. Arnold, USN, senior member; Comdrs. George L. Dyer and Charles J. Badger, USN; and Lt. Albert M. Beecher, USN, members; with Hudgins as member and recorder. Later, Comdr. Hugo Osterhaus, USN, and Lt. J. L. Jayne, USN, replaced Dyer and Beecher, respectively, and still later Comdr. George H. Peters, USN, took Badger's place.[6] The Bureau of Equipment provided the Board with complete instructions for carrying out the tests with, perhaps, little realization of their magnitude and complexity. These included, among other things, the comparison of the various sets under different conditions of use, influences

[4] Letter, dated 24 May, 1902, Chief of the Bureau of Equipment to the Secretary of the Navy; ltr., dated 26 May 1902, the Secretary of the Navy, to the Secretary of the Treasury, files, Bureau of Equipment, National Archives, Washington, D.C.

[5] Letter, dated 4 June 1904, Secretary of the Treasury to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington D.C.

[6] Letter dated 14 Aug. 1902, Acting Secretary of the Navy to Comdr. Conway H. Arnold, USN; letter, dated 18 Aug. 1902, Secretary of the Navy to Cmdr. Conway H. Arnold, USN, files, Bureau of Equipment, National Archives, Washington, D.C.

that might outwardly affect transmission, such as the effect of heat, fog, varying atmospheric conditions, atmospheric disturbances, and interference from any cause whatever. Upon convening, the Board inspected the Washington station, instructed the recorder to carry on with the work and to summons the Board when definite results were attained.

During the tests of any particular apparatus, only the manufacturer or his accredited representative was permitted to be present. This was to preclude competing manufacturers and other persons gaining knowledge of the results. Accordingly, from time to time, manufacturers' representatives did make their appearance to lend aid either in advising or to assist in obtaining better performance from their sets. M. Rochefort represented himself; the Slaby-Arco organization sent Messrs. Schiller and Kaiser;[7] the Braun-Siemens-Halske firm was represented by Mr. Korndorfer; and De Forest and his assistant, Mr. Harry Horton, were present during tests of the equipment of the De Forest Wireless Telegraph Co.

The instruction received by Bell and Bean at the European plants had been concentrated in such a short time, that the apparatus was even yet somewhat mysterious to them. They were joined by another chief electrician's mate, John Scanlin, who was to make a name for himself during the developmental years of this new science. Assembling and adjusting the sets called for skill and experience yet unattained, in appreciable measure, by these novices. Working under conditions[8] which certainly were not conducive to producing the best results and which would be unacceptable today, they, nonetheless, by guesswork and by trial and error, turned in a creditable performance, a great monument to their ingenuity and resourcefulness.

The period between 18 August and 9 October was utilized in testing the equipments of the four European manufacturers between the Washington and Annapolis stations. On 20 October the U.S.S. *Prairie* reported to assist in the tests for 10 days. Tests were made between Annapolis and the ship with Slaby-Arco and Braun equipments and communications were maintained up to distances of 90 and 100 miles, respectively. Following this, intermittent testing was conducted between Washington and Annapolis using the four types of European equipment or combinations of them with the De Forest apparatus until 6 January 1903. After that date further testing was suspended to await the assignment of a vessel for additional ship-shore tests.[9]

On 3 December 1902 the Board submitted an ad interim report on the tests conducted to that date. This was primarily concerned with the Slaby-Arco and Braun equipments and pointed out the superiority of the former. In a letter of transmittal to the Secretary of the Navy, Bradford expressed his great regret that the experiments had been interrupted by the lack of vessels

[7] Letter, dated 29 Aug. 1902, Algemeine Elektricitats-Gesellschaft to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[8] The following story of Mr. George Clark is illustrative of these conditions. "If anyone calls me, say I stepped out, Mr. Scanlin. I can stand God Almighty's lightning, but I can't stand his and Mr. Bean's at the same time." And with these comments, the ex-Confederate soldier, Scalemaster Whalen, stumped with his wooden leg out into a terrific lightning storm in the Washington Navy Yard. Half of his weighing house back of the Commandant's quarters, had been assigned to house the apparatus for the radio tests, and with such warnings confronting him as "60,000 volts, Deadly Keep Away," he was ill at ease. In spite of the terrific din made by the 1½-inch gap which Bean and Scanlan were using, Whalen stuck to his post, except when exposed to the combination of the two, when he sought refuge in a nearby storehouse. Such was the humble beginning of the U.S. Naval Radio Station, Washington, which would eventually be the major control of a world dominating network. The Physics and Chemistry Building at the Naval Academy contributed space and a table at Annapolis to the other test terminal, while the flag poles at the respective stations served to suspend the antennas ("Radioana," Massachusetts Institute of Technology, Cambridge, Mass. Clark, "Radio in War and Peace" (unpublished manuscript n.d.)).

[9] Report of the Wireless Telegraph Board, dated 28 Aug. 1903, files, Bureau of Equipment, National Archives, Washington, D.C.

and by the transfer of two members of the Board. He considered that no important results would be accomplished unless members of the Board could give their undivided attention to the project and be furnished with the necessary assistance.[10]

On 7 April 1903, the U.S.S. *Topeka* was assigned to assist the Board. For the next month ship-shore tests were conducted using the equipments of six manufacturers. During the final tests of each apparatus communications were maintained up to the following approximate distances:[11]

	Miles
Rochefort	25
Ducretet	43
Braun-Siemens-Halske	15
Slaby-Arco	52
De Forest	40
Slaby-Arco transmitter–Consolidated receiver	30

These tests were at times enlivened by unusual occurrences. While making a routine visit to the Naval Academy, the Secretary of the Navy became very much interested and engrossed in observing the operation of the De Forest equipment. He failed to notice a ground wire, over which he tripped and slightly injured himself. Horton, the De Forest operator, quickly sent a short account of the incident to De Forest in Washington, thus probably becoming the first radio press agent to report an unscheduled event. De Forest lost no time in telephoning the news to the Navy Department. On another occasion a reporter for the local newspaper, finding the tests at Annapolis a fruitful source of news, paid daily long visits to observe operations and wander around among the instruments. Finally, he made himself persona non grata. He was told to limit his visits to one a week, at which time he would be given a story. Indignant, he retaliated by providing his paper with a sarcastic account of the trials, the tenor of which was, "They are testing a so-called 'wireless' down at the Academy, but if you ask me they have enough wire strung between the mast and the Academy building to reach all the way to Washington." [12]

The ship-shore tests were followed by ones between two ships when the U.S.S. *Prairie* again returned to assist on 8 May. Lodge-Muirhead equipments, which had been ordered on 30 March 1903,[13] were added to the equipments. Comparative range tests were conducted until 14 July with the following results in reception in nautical miles: [14]

	U.S.S. *Topeka*	U.S.S. *Prairie*
Slaby-Arco	62	32
Ducretet	24	15
Rochefort	13	20
De Forest	54	54
Braun-Siemens-Halske	25	22
Slaby-Arco De Forest composite transmitter-Slaby-Arco receiver	26	33
Lodge-Muirhead	33	39

The Board completed its work on 20 July with a ship-shore test of the Lodge-Muirhead equipments. Communications between Annapolis and the *Topeka* were maintained up to a distance of about 30 miles.[15]

Throughout the period of these tests great difficulty was experienced in maintaining the equipment, most of which was not sufficiently rugged in construction to withstand the numerous moves and the rigors of shipboard use.[16]

In summary, in its final report, dated 28

[10] Letter, dated 3 Dec. 1902, Chief of the Bureau of Equipment to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[11] Report of the Wireless Telegraph Board, dated 28 Aug. 1903, files, Bureau of Equipment, National Archives, Washington, D.C.

[12] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass. (G. H. Clark, "Radio in War and Peace," unpublished manuscript, n.d.), p. 26.

[13] Letter, dated 30 Mar. 1903, Bureau of Equipment to Bureau of Supplies and Accounts, files, Bureau of Equipment, National Archives, Washington, D.C. The "estimated price" was quoted as $2500 for the two sets.

[14] Report of the Wireless Telegraph Board, dated 28 Aug. 1903, files, Bureau of Equipment, National Archives, Washington, D.C.

[15] Ibid.

[16] Ibid.

August 1903, the Board stated that its work was delayed and hampered by the lack of proper facilities, particularly in obtaining and holding ships for the carrying out of the ship-shore and ship-ship tests. Little opportunity was afforded to test composite equipments or to study the very important questions of tuning and selectivity. The extent of the work done in those matters was to note to the extent to which atmospheric electric discharges, neighboring transmitting stations, and other local disturbances interfered with the communications between the stations. It pointed out that experimental work was necessarily slow, especially in a new field where the effect of the slightest change had to be determined by long and repeated tests. The work of the Board was also delayed by the lack of a sufficient number of trained operators, since this necessitated utilizing considerable time for familiarization. It opined that this lack of operators would be acutely felt when the contemplated installations on ships and at shore stations were completed, and that immediate action should be taken to provide additional facilities for training. The questions of the advantages of different locations on shipboard for the instruments and radically different arrangements of antennas were not resolved; rather it was concluded that they should be determined experimentally for each ship, or at least for one ship of each class.[17]

The final recommendation of the Board stated:

> In considering the results of tests conducted and the action of the instruments during tests, the board is of the opinion that the Slaby-Arco apparatus is the one best adapted to naval use among all the various systems tried, not only on account of its greater range, but also on account of its reliability, freedom from interference, adjustability, and ease of manipulation by unskilled or poorly trained operators, and the Board therefore recommends that sufficient sets of this apparatus be purchased to install on naval vessels and shore stations which it is desired to equip.[18]

[17] Ibid.

[18] Ibid.

PURCHASE OF ADDITIONAL EQUIPMENTS

By the spring of 1903 the tests had produced sufficient indication of the superiority of the Slaby-Arco equipment to warrant, after consultation with the senior member of the Wireless Board, the purchase of additional numbers of that equipment. On 27 March 1903, the Bureau placed an order for 20 sets, with the delivery being requested by midsummer. The total price paid for these 20 model 1903 Slaby-Arco equipments was M86,000.00.[19]

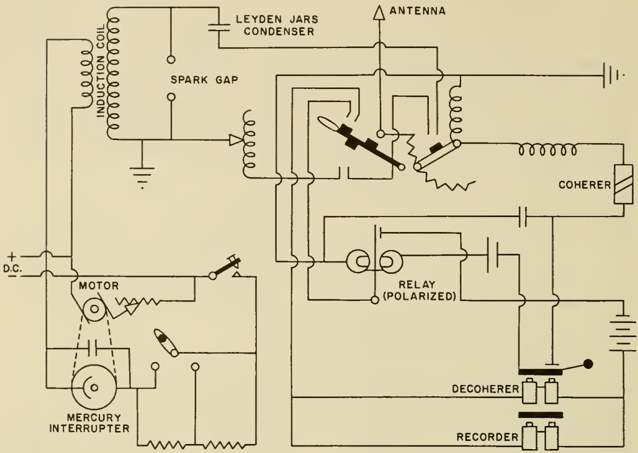
Following receipt of the Wireless Telegraph Board's final report, the Bureau, on 10 September 1903, placed another order for 25 Slaby-Arco equipments. When the delivery of these was made, the total number of this manufacture owned by the Navy was 47. Including 10 of other manufacture, the grand total of complete usable equipments was 57.

REPERCUSSIONS FROM AMERICAN MANUFACTURERS RESULTANT OF SLABY-ARCO PURCHASES

Following the early 1903 purchase of Slaby-Arco equipment, one American firm immediately lodged a protest. In early May 1903, Fessenden, of the National Electric Signaling Co., informed the Secretary of the Navy that for some years his company had been developing a system of radiotelegraphy which, in his own words, "is believed to be superior to any other on the market." He stated that he had received no notification regarding tests and that he had noticed in the press that 30 sets of apparatus of foreign manufacture had been purchased by the Navy Department. He suggested that, prior to making large purchases of foreign built equipment, his system which had been developed by Americans should be given a

[19] Letter, dated 8 Apr. 1904, Chief of the Bureau of Equipment to Comdr. F. M. Barber, USN (retired), files, Bureau of Equipment, National Archives, Washington, D.C.

Diagrammatic Sketch of Slaby Arco Equipment
Purchased by The United States Navy in 1903



Reconstructed from Information Contained in an Article in notes on Naval Progress, 1902 by Lieutenant Charles H. Poor, U.S. Navy and from the Official Report of the Wireless Telegraph Board, Dated 28 August, 1903 and Other Official Navy Records

FIGURE 8–1.

trial. Additionally, he claimed that the purchased foreign apparatus infringed the patents owned by his company in various respects, and that, if the Navy finally decided to purchase such foreign apparatus without testing his system, he would be glad to be informed as to the proper method of obtaining redress for the infringement of his methods.[20]

On 7 May 1903, he was informed of the earlier correspondence with Queen & Co. and of the non-receipt of the promised information. In replying, he stated that he was unaware of this correspondence and that he had no connection with that firm.[21]

[20] Letter, dated 2 May 1903, Reginald A. Fessenden to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[21] Letter, dated 8 May 1903, Secretary of the Navy to Reginald A. Fessenden, "Radioana," op. cit., files, National Electric Signaling Co.

Upon receipt of this information, he was requested to submit proposals,[22] which he promptly did, quoting a price of $2,000 per set, with delivery within six weeks, and with a guarantee of distance coverage of from 50 to 200 miles when used with antennas 50 to 150 feet in height and a power of sixty watts.[23]

Without awaiting reply, Fessenden, in the same month, proposed furnishing two sets, with operators, at his own company's expense. He was directed to contact Capt. C. H. Arnold, USN, Senior Member of the Wireless Telegraph Board,[24] then in the U.S.S. *Prairie,* operating out of Hampton Roads, Va. After discussion, Arnold offered him the week of 21 June for tests, but on 13 June Fessenden withdrew his offer, stating:

> On account of pressure of other business, and the fact that the apparatus constructed for this test would be special and could not be used elsewhere it is not certain that our Company would dare to supply apparatus at its own expense and it would probably be better for the Department to do as it had done in the case of the other companies, i.e., order from us a couple of sets of apparatus wound to meet your requirements. These we would be willing to furnish for the sum of $5,000.00 it being distinctly understood, however, that this price was not to form a precedent but is merely made so that you can arrange to test our apparatus at as little expense to the Department as possible.[25]

In the interim, Fessenden demonstrated his equipment to Hudgins at Fortress Monroe, and, in informal conversations, provided details and outlined its advantages. Fessenden advised the Board that, as of 23 July 1903, there were Fessenden stations in actual operation at Cape Charles City, Old Point Comfort, and Ocean View, Va.; New York City; Philadelphia; and Point Reyes, Calif., and in several places in Brazil. The Board asked him to provide them a list of stations he contemplated establishing within the next 6 months, to which he replied:

> I would say that we have not yet decided as to the exact points but we do expect to erect some thirty or forty stations during that time.[26]

On 5 September 1903, he wrote the Secretary of the Navy a letter from which the following is quoted:

> I should also like to have an interview with you to secure some information as to the best means of taking up the question of royalties on apparatus which are due us from the Navy. As you are aware, the Navy has purchased some twenty or thirty sets of Slaby-Arco apparatus which apparatus infringes a number of our most important patents. In fact, the Slaby-Arco people would not be able to operate more than a few miles if it were not for the fact that they are using the methods invented by us and covered by our U.S. Patents. These patents have been investigated by Messrs. Kenyon & Kenyon, who are perhaps the most eminent patent lawyers in this country, who have declared them valid and sustainable in court.
>
> We therefore are desirous of taking the proper steps to secure the royalties due us from the Navy for the use of our patented apparatus as used by the Slaby-Arco people. These royalties will amount to somewhere in the neighborhood of $3,000.00 per set and the total will therefore amount to considerable.

This letter continued with Fessenden inviting attention to the difference in the attitudes of the United States and German Governments relative to radio. In Germany, Professor Slaby had been granted considerable sums of money and every possible assistance, including a decoration by the Kaiser and the adoption of his system by his Government. This, "in spite of the fact that the forms are largely made up of methods devised and patented by us and by the Marconi Co." In contrast with the actions of the German Government, in the United States, where his firm had spent in excess of

[22] Letter, dated 7 May 1903, Secretary of the Navy to Reginald A. Fessenden, "Radioana," op. cit., files, National Electric Signaling Co.

[23] Letter, dated 8 May 1903, Reginald A. Fessenden to the Chief of the Bureau of Equipment, "Radioana," op. cit., files, National Electric Signaling Co.

[24] Letter, dated 21 May 1903, Chief of the Bureau of Equipment to Reginald A. Fessenden, files, Bureau of Equipment, National Archives, Washington, D.C.

[25] Letter, dated 13 June 1903, R. A. Fessenden to Capt. C. H. Arnold, USN, Senior Member, Wireless Telegraph Board, "Radioana," op. cit., files, National Electric Signaling Co.

[26] Letter, dated 23 July 1903, R. A. Fessenden to Capt. C. H. Arnold, USN, "Radioana," op. cit., files, National Electric Signaling Co.

$100,000 to date in experimental work, and had devised apparatus which "is vastly more sensitive and very much more reliable, which can be used for sending code messages in all kinds of weather and which is very much more free from outside disturbances," the Government declined to purchase a single set of apparatus. He deplored the fact, that, far from giving him any encouragement at all, it had gone abroad to buy equipment which "is not only very much inferior to ours but which obtains what value it has from the fact that it is an embodiment of the ideas invented and patented by us." He opined that such a state of affairs would cease to exist when brought to the attention of the Secretary of the Navy. He, therefore, requested a personal interview in order to resolve the matter in the shortest possible time.[27]

In another letter, less than two weeks later, also addressed to the Navy's Secretary, he brought out numerous points, among which he noted the following:

> That the United States inventor's apparatus was offered to the Navy at less than actual cost of manufacture, i.e. $2,500 and that even in lots of 50, the apparatus gives but a small profit when sold for $4,000 per set. The lowest price offered to other parties has been $5,000 per set, this giving a 40 percent profit or less.
>
> That if the German manufacturer had to pay the same price for labor as is paid in America or had to pay duty, and if he forwarded the apparatus complete to the same extent as the American inventor, he could not sell it for less than $2,500.
>
> That if the German inventor had to pay the heavy expense of making his own inventions instead of appropriating American inventions, and if he had no more encouragement from his own government than the American inventor had from the United States Government, he could not sell the apparatus for less than $5,000 per set.
>
> That the Slaby-Arco apparatus will not operate to any useful extent without infringing the American inventor's patents.[28]

Upon receipt of this letter, the Secretary decided that prior to granting his requested interview it would be best to obtain some knowledge of this individual who was continually flooding his office with complaints. Since Fessenden had recently been in the employ of the Department of Agriculture, he requested a written opinion of him from the Secretary of Agriculture. The Department of Agriculture's reply was forthcoming within the week. It stated that Mr. Fessenden had been employed in the Weather Bureau from 19 January 1900 to 31 August 1902, but had been suspended for "disobedience of orders and insubordination" and had resigned while under this suspension. It confirmed the fact that Fessenden had patented a number of devices but stated that they were of dubious value. He was said to be "intractable and insubordinate as an employee, unreliable in his statements and extravagant in his claims as to the performance and possibilities of his inventions." [29]

Following receipt of information concerning the Navy's additional purchase of 25 Slaby-Arco equipments, he wrote numerous letters belaboring the matter. In one, dated 20 February 1904, he observed that, as the result of Navy tests on apparatus of other makes, a system was selected and "it was understood that between 50 and 70 sets have been purchased." Such being the case, he could not refrain from "respectfully petitioning" that the National Electric Signaling Co. "be permitted to enter suit against the U.S. Navy for damages for the use of our devices." [30] The Navy Department replied, "Any action by this Department attempting to confer jurisdiction upon the Courts where, by the law it does not already exist, would be a mere nullity, as the Department has no authority in that respect." [31] This was not the end of

[27] Letter, dated 5 Sept. 1903, R. A. Fessenden to the Secretary of the Navy, "Radioana," op. cit., files, National Electric Signaling Co.

[28] Letter, dated 17 Sept. 1903, R. A. Fessenden to Secretary of the Navy, "Radioana," op. cit., files, National Electric Signaling Co.

[29] Letter, dated 19 Sept. 1903, Secretary of Agriculture to Secretary of Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[30] Letter, dated 20 Feb. 1904, from R. A. Fessenden to Secretary of the Navy. "Radioana op. cit., files, National Electric Signaling Co.

[31] Letter, dated 1 Mar. 1904, Secretary of the Navy to R. A. Fessenden, "Radioana," op. cit., files, National Electric Signaling Co.

the difficulties which would be caused by this self-opininated, highly tempered individual.

While Fessenden was writing his contentious letters to the Secretary of the Navy, the Marconi interests were analyzing their position. Their right of monopoly was being questioned internationally,[32] and the sale of Slaby-Arco equipment to the U.S. Navy further weakened their position. In an endeavor to ensnare the Navy, they, on 30 November 1903, inquired if it would consider the use of its apparatus on its ships under certain conditions, "which we trust is analagous to arrangements with other private commercial interests to which your Bureau has consented." In summarizing the salient portions of the proposed agreement, the company stated it would furnish its latest and improved apparatus complete, each set to be marked "For use of U.S. Navy only," in addition to its regular and patent marks, for $2,265 per set, to be paid at time of delivery as full rental for the life of the apparatus or patents, all apparatus when useless or worn out to be returned to the Marconi Co.[33] This effort was sown in fallow soil.

[32] The First International Radio Telegraph Conference had been held in Berlin and had drafted a protocol aimed at the elimination of any radio monopoly (infra, ch. VII).

[33] Letter, dated 30 Nov. 1903, Marconi Wireless Telegraph Co. of America to the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washintgon, D.C.

CHAPTER VI

Early Naval Radio Installations and Problems

ORGANIZATION

One of the greatest deterrents to the early rapid development of naval radio communications was the lack of a close knit organization. Ashore, the stations were under the military command of the commandant of the naval yard or station closest to them. Operationally, they were responsible both to that commandant and to the Chief of the Bureau of Equipment, through the head of its Radio Division. Afloat they were militarily and operationally responsible to the senior commander, via the chain of command. Since the Navy, at that time, was composed, more or less, of independent squadrons operating directly under the Secretary of the Navy, there was no unified direction of radio activities afloat. In these individual squadrons, radio operation fell within the purview of the flag lieutenant, who, although usually sufficiently versed in visual signaling methods, lacked knowledge of or interest in this new field. Aboard individual units, the personnel came under the direction of the senior operator who quickly became a law unto himself. Budgetary and maintenance responsibilities, afloat and ashore, were the province of the Bureau of Equipment.

INITIAL ESTABLISHMENT OF U.S. NAVAL RADIO STATIONS

Following the spring 1903 purchase of 20 Slaby-Arco equipments, action was immediately initiated to obtain final decision as to the shore radio stations to be established and the ships to be fitted. The Bureau of Equipment recommended establishing stations on the lighthouse reservations previously approved by the Secretary of the Treasury and additional stations at Cape Elizabeth, Maine; Cape Ann, Mass.; Cape San Juan, P.R.; and on Corregidor Island, and at Cavite Navy Yard, Luzon, Phillipine Islands.[1] These recommendations were referred to the Navy General Board, Adm. George Dewey, USN, President, which commented to the effect that radio telegraph stations would be a valuable adjunct to the Naval Patrol Service, lately established by the Navy Department, and as soon as that service was organized the commandants of the several naval districts would be called upon to name the points in their districts where such stations were desirable. The General Board would then be able to make a comprehensive recommendation covering the whole coast. In the meantime, however, in order not to delay the establishment of stations at points proposed by the Chief of the Bureau of Equipment, which stations would undoubtedly be included in the general plan, it was recommended that his requests be approved in connection with the stations on lighthouse reservations and that the Secretary of War be asked to allow the Navy to erect a station on Corregidor Island.[2]

The Wireless Telegraph Board recom-

[1] Letters, dated 1, 4 and 7 May 1903, Chief of the Bureau of Equipment to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[2] Letter, dated 21 May 1903, President, Navy General Board to the Secretary of the Navy, files, Secretary of the Navy, National Archives, Washington, D.C.

mended that, owing to a lack of trained operators, only the shore radio stations at Cape Elizabeth, Maine; Newport, R.I.; Montauk Point and Brooklyn Navy Yard, N.Y.; and the Highlands of Navesink, N.J., be established prior to the summer maneuvers of the North Atlantic Fleet. The Board, recognizing the importance of establishing all the shore stations as soon as possible, recommended the following be equipped as soon after the summer maneuvers as trained operators became available: Portsmouth Navy Yard, N.H.; Thatchers Island, (Cape Ann), Boston Navy Yard and Highland Light (Cape Cod), Mass; Cape Henry and Norfolk Navy Yard, Va.; and Pensacola, Key West, and Dry Tortugas, Fla. In order to insure the availability of sufficient apparatus, it was suggested that the apparatus used during the comparative tests be modified and used at the less important shore stations such as the Norfolk Navy Yard, the San Francisco Training Station, and Annapolis,[3] where their shorter range would not be a material disadvantage.

The shore stations to be used during the summer maneuvers were immediately equipped and placed into commission. Following the completion of the exercises all the additional stations except Norfolk Navy Yard and Dry Tortugas were established. These all became units of the U.S. Naval Radio System.

INITIAL FLEET INSTALLATIONS

Early in June 1903, the Secretary of the Navy was advised that it would be practicable to equip battleships of the North Atlantic Fleet with radio telegraphic apparatus within one month, and that on each ship some work would be required which was under the cognizance of the Bureau of Construction and Repair. Authority was given to equip the battleships of the North Atlantic Fleet, and the Bureau of Construction and Repair was directed to perform the necessary alterations. Without guiding precedents, the major task was the determination of the best location for the instruments. It was decided to make temporary installation on each ship, at a location determined by theoretical considerations, as the one which would permit operation at maximum efficiency. The permanent location would later be determined by practical experiment and when known, the installation would be set up in a permanent manner.[4]

In June 1903, the Boston, New York, Norfolk, Mare Island, and Puget Sound Navy Yards were provided guidance to assist them in fitting radio equipment in naval vessels. Specifications called for a dry, well lighted, and ventilated compartment, about 6 feet square, with the full "in-between" deck height and provided with direct communication by voice or telephone to the bridge. If possible, the compartment should be located below armor and, in case the antenna was suspended from the foremast, it should be aft, at about the after bridge or mainmast. Where a special space had to be provided in a between-deck space, the bulkheads could be of either wood or light metal. A plain table or bench about 6 feet long and 30 inches high, of well-seasoned soft wood, capable of supporting a maximum weight of about 500 pounds was required for the instruments. Bulkheads above and below the table would be covered with soft wood for mounting rheostats and other instruments not required on the table. The Leyden jar battery with the spark gap was required on the table. Six to eight cubic feet of storage space were required for spare parts and supplies.[5]

[3] Letter, dated 10 July 1903, Senior Member, Wireless Telegraph Board to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[4] Letter, dated 10 June 1903, Chief of the Bureau of Equipment to Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[5] Letter, dated 18 June 1903, Chief of the Bureau of Equipment to the Commandants of the Boston, New York, Norfolk, Mare Island and Puget Sound Navy Yards, files, Bureau of Equipment, National Archives, Washington, D.C.

The specifications directed that the antennas would lead from the radio compartment through a hard rubber insulator in the deck above the table and be kept as far as possible from the ship's structure and rigging by insulator and guys, on a diagonal lead to the fore truck. A clean direct connection to the ship's hull was specified as a ground. The power leads had to be capable of carrying a momentary overload of about 30 and a normal current of 10 to 12 amperes, without material drop in voltage, and should be direct from the main switch board if feasible, otherwise from lighting or power circuits.[6]

The Bureau directed that radio rooms be fitted on all ships that were to be equipped with radio apparatus as soon as their navy yard availability would permit. The commandants of the navy yards were requested to direct their equipment officers to confer with the naval constructors, select spaces for stations, and submit estimates of time and cost for fitting such spaces on all steel ships over 2,000 tons displacement, except monitors and auxiliaries, and to submit the same to the Bureau for approval.[7]

In the same letter in which they made recommendations as to the shore radio stations to be established, the Wireless Telegraph Board suggested that the following ships be fitted before participating in the summer maneuvers of 1903: U.S.S. *Illinois, Kearsage, Maine, Olympia, Baltimore,* and *Texas.* They further suggested that the equipment in the U.S.S. *Prairie* and *Topeka* be modified to permit operation with Slaby-Arco equipments.[8]

At the time the Slaby-Arco sets began to arrive, the ships were concentrated at Bar Harbor where the task of supervising the temporary radio installations on the U.S.S. *Illinois, Kearsage, Olympia, Baltimore,* and *Texas* and instructing the future operators, was entrusted to John Scanlin, one of the chief electrician's mates who had participated in the comparative tests. He was handicapped, in that he possessed only a vague idea of how to tune the equipments and lacked practice with the filings coherer, but he is credited with a remarkable performance in assembling the equipment and making it work satisfactorily. To further complicate his problem only signalmen were available as operators, and he had little opportunity to provide them training. To them the new devices were foreign in more ways than one, but their experience in signaling with blinker lights and their knowledge of the Navy or Meyer code, which was adopted for radio use in the forthcoming exercises, alleviated the situation somewhat. With perserverence, blustering, and coaxing, Scanlin managed to train them to tune and operate a radio set. The installations were all complete and in working order prior to the commencement of the August exercises.

THE NAVY'S FIRST STRATEGIC USE

In the 1903 summer maneuvers the North Atlantic Fleet was divided into two forces. The "White Squadron," or attacking force, was under the command of Rear Adm. James H. Sands, USN; and the "Blue Squadron," or defending force, was commanded by Rear Adm. F. J. Higginston, USN. Rear Adm. Albert S. Barker, USN, commander in chief of the North Atlantic Fleet, was the umpire in chief.[9]

The White Squadron, composed of the U.S.S. *Texas, Massachusetts,* and *Indiana* and the destroyers U.S.S. *Truxtun, Whipple,* and *Worden,* was directed to take station 500 miles east of Cape Cod, Mass., and from that point to attempt to capture and hold for a specified period of time, the mined portion of the coast between Cape Cod and Eastport, Maine.

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[6] Ibid.

[7] Ibid.

[8] Letter, dated 10 July 1903, Senior Member, Wireless Telegraph Board to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[9] Albert S. Barker, "Everyday Life In The Navy," (the Gotham Press, Boston, 1928.), p. 386.

The Blue Squadron, with the mission of discovering and destroying the enemy before he was able to establish his "beachhead", was made up of the remainder of the available ships of the North Atlantic Fleet which included, among others, the radio-equipped U.S.S. *Kearsarge, Olympia, Illinois,* and *Prairie.*

Prior to the commencement of the exercise, Scanlin constructed two simple contact report codes, using the name of flowers as code words in the one for the attacking force, and of metals in the one for the defending force. He instructed the operators of the attacking force that in the event that they heard the name of metal in any radio transmission they were to immediately hold their key down in an effort to jam the transmission.[10]

The White Squadron departed Frenchman's Bay, Bar Harbor, Maine, on 3 August and proceeded to a specified position. The Blue Squadron was not permitted to depart from Frenchman's Bay until 5 August, and on that day the main body, consisting of the *Kearsarge, Alabama* and *Illinois* took a central position off Baker's Island while the remainder of the ships instituted their search.[11]

Rain, mist, and fog hindered search operations for the next 3 days, and necessitated that the scouts fall back on the coast. At about 0345 on the 8th, operators observed the word "gold" coming in on the tape registers. This was the instant that the operator on the *Texas* should have held down his key to jam the transmission—but nothing happened and the remainder of the message was received. It contained the information that the Olympia had sighted the attacking force 25 miles south by east of Mount Desert Rock Lighthouse. By 0700 the defenders had captured them before they could even approach the coast.[12]

As soon as they came into port, Scanlin, who had been in the *Kearsarge* during the exercise, took a boat to the *Texas* to determine what had occurred. Once on board, he found the radio room locked and learned from the officer of the deck that the operator was in the brig. He was allowed to talk to him and this is the story told by that unhappy signalman:

> I was on watch and everything was working fine. I heard a message begin, and the first three letters were G, O, and L, so I knew it was going to be "gold" and that it was from the other side. I reached for the key, but the Flag Lieutenant, who was with me said "No don't do that I want to get the entire message". When the message was ended, the Lieutenant said "Make interference," and I said "Sir, it's no use now. The message has gone out with a speed of 186,00 miles a second and we can't catch up with it." So here I am on bread and water.[13]

The flag lieutenant was Lt. T. P. Magruder, USN, who later as a rear admiral, was to earn, by his utterings. considerable publicity and a long suspension from active duty.[14]

To the defending and also winning Commander, Higginston, the use of radio in the maneuvers was quite successful. He commented:

> To me the great lesson of the search we ended today is the absolute need of wireless in the ships of the Navy. Do you know we are three years behind the times in the adoption of wireless? [15]

Admiral Barker, the umpire of the maneuvers later wrote:

> The maneuvers, particularly those connected with the search problem had demonstrated to my satisfaction that wireless, which many people then considered a foolish try, had come to stay; that it was capable of development and would be of great use in time of war and in peace. I so reported to the Chief of the Bureau of Equipment who asked my opinion, and I am informed that my report influenced him to continue his efforts to develop the system and to purchase more sets of instruments.[16]

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[10] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass. (G. H. Clark, "Radio in War and Peace", unpublished manuscript, n.d.), pp. 30–31.

[11] Ibid.

[12] Ibid.

[13] Ibid.

[14] Ibid.

[15] "Radioana," op. cit., (G. H. Clark "History of Early Wireless Telegraphy", unpublished manuscript, n.d.) .

[16] Barker, op. cit., pp. 386–392.

Following the exercises the fleet departed for Oyster Bay, N.Y., to participate in a presidential review. Scanlin was assigned to the *Texas* for the duration of the trip for the purpose of checking and adjusting her radio equipment. He discovered that Magruder had not liked the unsymmetrical appearance caused by the antenna being guyed well clear of the stacks and rigging, and had ordered it changed so that it almost touched the stacks, causing corona discharges during transmissions with the resultant dimunition in the strength of the emitted signal. Magruder expressed himself to the effect "he didn't give a damn about wireless . . . but he did give a damn for the appearance of the ship . . ." Everything was going to be symmetrical and shipshape if he had anything to say about it, and the radio antenna was not going to detract from its appearance. He did not have much to say about it; the antenna was again guyed away from the stacks and rigging.[17]

THE OPPOSITION OF SENIOR OFFICERS

The commercial interests were not providing the sole opposition to the program of establishing a system of naval radio communications. Archer, in his "History of Radio to 1926" states:

> There were captains and even admirals who were so reactionary in their views and so jealous of their perogatives while on the high seas that they resented the idea of receiving orders by wireless. They opposed with might and main the new agency of communications.[18]

Unfortunately, the record supports Archer in this criticism. No serious effort was made by the various commanders to organize, utilize, or supervise radio communications within the fleet. It was used to a limited extent for strategic purposes, but very little dependence was placed upon it for tactical purposes. The Annual Report of the Secretary of the Navy, 1904 describes the purposes for which it was considered effective when it states:

> . . . greatly facilitated the dispatch of business. Doubtless the meaning of the terms "beyond signal distance," "within signal distance," and "senior officer present" may be modified somewhat in the future on account of the introduction of wireless telegraphy.[19]

Even such an early advocate of a system of electrical communications without wires for naval usage as Comdr. Bradley A. Fiske, USN,[20] joined the ranks of those who were critical of the new medium. Since he was a recognized authority on electrical installations, his remarks caused considerable comment. The Army and Navy Journal of 20 February 1904, noted that among the contents of the current number of the Proceedings of the United States Naval Institute was a timely article on "War Signals" written by him, in which he advanced the rather startling proposition that while the Navy had "adequate means for signaling in time of peace, it has no system that could with certainty be depended upon for all purposes in time of war." It noted that he vigorously opposed the notion that the installation of radio equipment had solved the problems of war signaling, and was inclined to the opinion that radio had no military usefulness whatever, believing its convenience in peace tended to encourage officers in the practice of handling squadrons by a system that would be worthless and perhaps dangerous in war. Even if made tunable, the enemy, as Fiske pointed out, could soon discover the frequency and imitate it, even if he could not read the signals, or he might even interfere by transmitting with abusive power. "What Admiral", he asked, "is going to fill the ether with Hertzian waves and thus make a present to the enemy of the information that he is near?" In pointing out the limitations of the new medium it was hinted that

[17] "Radioana," op. cit., (G. H. Clark, "Radio in War and Peace," unpublished manuscript, n.d.), pp. 30–31.

[18] Gleason L. Archer, "History of Radio to 1926," (the American Historical Society, Inc., 1938.), p. 73.

[19] Annual Report of the Secretary of the Navy, 1904, p. 530.

[20] Supra, p. 18.

he had laid himself open to the charge of assuming that no invention would ever be made which would prevent interference.

In a letter to the Army and Navy Journal in March 1904, he sought to clarify his position by suggesting that the same process of reasoning would apply to the belief that an invention can be made which will prevent the prevention of interference. He stated:

Why should we suppose that inventors will confine their efforts to preventing interference, when military reasons will make it equally desirable to prevent preventing? And the more clearly the laws are understood whereby "interference" can be prevented the more clearly the laws will be understood whereby preventing can be prevented; that is the better the laws of the game are understood, the better both sides will play it.

Therefore (no matter how much or how little we think invention can do in this matter), is it wise to base our whole system of fleet handling, and to stake all our chances of victory in war on the hope that someone will invent a means of preventing "interference," and that no one will ever invent another means that will counteract it?

CHAPTER VII

The Origins of Regulation

COMMERCIAL RIVALRY

The years 1902 and 1903 saw interest in radio increasing rapidly with the number of stations mushrooming, with their operations completely free and unrestricted. Commercial rivalry in the field was increasing in this country, much as it had in Europe a few years before. Unregulated competition, and the interference incident thereto, began to present a problem. Although some form of regulation had been advocated ever since the turn of the century, in this Nation, dedicated to the philosophy of free enterprise, it was slow in materializing.

The Marconi interests were making rapid progress in establishing their radio monopoly by constructing shore stations in all the principal maritime countries. These stations were prohibited from handling messages from ships which did not lease Marconi equipment, thus making it undesirable for shipowners to equip their vessels with equipment of other manufacturers since such equipment would have limited use. The Marconi companies cannot be adjudged guilty of stock peddling. Although most of them operated under deficits for almost a decade, they made no fanciful promises to investors.

In the United States the American De Forest Co. was the only serious competitor of the Marconi interests.[1] Their ship installations were leased at far more reasonable costs but their business was almost totally limited to vessels engaged in the coastwise trade.

By 1903 Gehring's Consolidated Co., now the International Co., and White's American De Forest Co. were both engaged in selling stock in a most unscrupulous manner. The success of Gehring in this field caused considerable concern to White, who, desiring to monopolize the entire "watered stock" promotion field, succeeded in obtaining control of and absorbing International Co.

Shoemaker, one of its engineers, went into the employ of the De Forest Co. Pickard, its other engineer, refused such employ and established his own laboratory at Amesbury, Mass.[2]

A brochure, issued at that time by the American De Forest Co., after it had adsorbed the International Co., contained the following notices:

> This consolidation brings to the American De Forest Co. 80 more patents and nine coast stations, and "practically" puts under one management, with the elimination of competition, every wireless company with patents of any value existing on this side of the Atlantic.
>
> The De Forest corps of scientists: Lee De Forest, Ph.D., Prof. Harry Shoemaker, electrical engineer of the International Co., J. E. Ives, Ph.D. formerly professor in University of Cincinnati.[3]

Following the merger of the De Forest and Gehring interests, White ran things

[1] In order to restrict activities of American De Forest Company, Marconi Wireless Telegraph Company of America instituted infringement proceeding against them. Judge W. K. Townsend, U.S. Circuit Court rendered a decision in favor of the plaintiff in May 1905.

[2] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., SRM5–020.

[3] Brochure, American De Forest Co., "Recent Developments in De Forest Wireless Telegraph," n.d.

with such a high hand that his fellow promoters made attempts to wrest control from him. By raising the cry of "conspiracy," he made the most of this by turning it into additional publicity. In retaliation of Gehring's attempt to force White to bring the firm's books into court, the latter brought suit for damages against him and six other "conspirators." The whole trouble between White and the seven "conspirators" was that the latter considered they were not getting their share of the "spoils." The trouble was patched up, White settled with the malcontents, and then forced them out of the company.[4]

In absolute control of the $15,000,000 company, and with no competitor except Marconi, White went along swimmingly for a year or more. By making wild promises to investors as to what he was going to do with the De Forest system, he sold large quantities of stock. Much of the money from these sales was appropriated to his own use, and most of the remainder was spent in publicity. He almost bankrupted the company in erecting stations throughout the country, one of them being at the Louisiana Purchase Exposition. Some of these stations were too remote from each other to send any messages at all, and many were run at a loss. But they were great "come-ons" to investors, and were the means of selling more stock. The De Forest Co. was really making more headway in this country than the Marconi, despite the fact that it was very expensive progress. White confessed to some of his intimate friends that he didn't know how the company would ever become solvent, but told quite another story to investors.[5]

This corporation, dedicated more to the idea of selling stock than to establishing a system of communications, was destined to

[4] Frank Fayant, "The Wireless Telegraph Bubble," Success magazine (New York), vol, X, no. 157, June 1907, p. 450.

[5] Ibid., p. 450. Illustrative of these tales is the following quotation from a brochure of American De Forest Wireless Telegraph Co. distributed in 1905: ". . . in order to quickly extend the business of the company, a rare opportunity is offered in the $500,000 issue of first mortgage bonds and the $500,000 of stock given as a bonus. Bonds are issued in the amount of $100 and $1,000. No stock is offered for sale except as a bonus with the bonds. With each $100 twenty year 6 percent gold bond you get a bonus of $100 in common stock which may be worth $25,000 in a few years; besides you are given the valuable privilege until December 1909 of converting the bond at par into 7 percent preferred cumulative and participating stock at par, even though the preferred stock should advance in value many hundreds or thousands percent. The company owns over 100 patents covering every phase of rapid wireless telegraphy, and includes several hundred claims which cover wireless appliances radically distinctive in principle and eminently superior to those of other systems, as has been proven by the United States and foreign governments in public and private tests.

All the foreign systems use the Branly coherer or an adaption of the same. This coherer-receiver was invented in 1891, made known to the public, and is beyond protection of patent. In place of the coherer-receiver the De Forest system uses electrolytic and anti-coherer receivers operated on principles dicovred by Dr. De Forest and protected by basic patents. This fact gives the De Forest system a speed of transmission two or three times as great as the various coherer systems, greater sensitiveness permitting longer distance of communication, and unequaled freedom from atmospheric disturbances, insuring regular uninterrupted communication at all seasons of the year, both over land and water. The De Forest System stands alone in the possession of syntonic or tuning devices, which actually prevent interference with messages, or the cutting in of other offices, not desired by the office sending the message. This essential apparatus is fully protected by several basic patents embracing 103 claims.

These appliances enable many wireless stations in close proximity to be operated simultaneously for different messages without interference with each other. Without these devices, universal commercial wireless telegraphy is impossible, but with them, wireless telegraph can replace all existing telegraph and cable lines.

The De Forest Company has relay devices for the automatic forwarding of messages from station to station. The message travels at the rate of 186,000 miles per second.

The De Forest Automatic Forwarding Apparatus can be accurately gauged to send out signals a given distance. The De Forest Range Finder receives and measures the distance from the signal forwarding station. The De Forest Localizer determines the direction from which messages are sent.

The American De Forest Company has constructed fifty stations and has one hundred and seventy-two under construction or arranged for.

Steamers of the Mallory Line, New York & Porto have its troubles. Other companies were not content to let it go merrily on its way, degrading the young industry and defrauding the public, nor especially where the Marconi interests unaware of its challenge to their attempts to establish a monopoly. In addition to the previously mentioned patent litigation instituted by the American Marconi Co., the National Electric Signaling Co. filed suit against it for infringement of their patents. In October 1905, Judge Wheeler, of the United States Circuit Court for the Southern District of New York, rendered decision upholding the Fessenden patent on the electrolytic detector and adjudging it infringed by the American De Forest Wireless Telegraph Co. These were but the beginning of many patent infringement suits which would plague the radio interests for years and which would be finally resolved only with the aid of the Navy.

Regardless of these decisions against his company, White, who would later serve as a guest at a Federal penitentiary for his misdoings and who would eventually take his final rest in a pauper's grave, proceeded with his practices of swindling the American public.[6] Had De Forest secured honest support in his enterprises, it is possible that he would have met a degree of success which might have changed the status of commercial radio. However, to use the words of Mr. Owen D Young:

> Fifteen years is about the average period of probation, and during that time the inventor, the promoter and the investor, who see a great future for the invention, generally lose their shirts . . . This is why the wise capitalist keeps out of exploiting new inventions and comes in only when the public is ready for mass demand.

Rico Steamship Company and the Quebec Steamship Company are equipped by the American De Forest Company. Twelve United States Government stations, including Nome and St. Michael's, Alaska and Weather Bureau stations on the Pacific Coast use the De Forest system.

The United States Navy alone is planning to erect and install nearly one hundred coast stations.

"There are over three hundred United States government vessels yet to be equipped. The American De Forest Wireless Telegraph Company has as complete a monopoly on the essential devices necessary to universal commercial wireless telegraphy as the Morse system had on wire telegraphy and as the Bell Telephone Company enjoyed during the life of their basic patents on the essential devices necessary to its commercial use. Long-distance stations with a capacity of 2,000 miles are being installed in principal cities, and short distance stations with a capacity of 150 to 200 miles are being installed in the smaller cities and towns to connect with long-distance circuits.

"There were eight preceding Morse who made progress in wire telegraph but it was the invention of Morse that made it a commercial success; so it is in Wireless Telegraph. Several have made progress in its use, but it remained for Professor De Forest to invent the devices necessary to its universal commercial use and to send and receive long-distance messages."

INTERFERENCE BETWEEN STATIONS

The Marconi endeavors to create a monopoly, and the unsavory business dealings of the De Forest Co. were not the only reasons which called for some degree of Government regulation of the young science. Amateurs with their home-constructed equipment began increasing by the scores, and the interferences created by them in large metropolitan areas began to pose additional problems and complications. Early in 1902, concern over this problem of interference was manifested by naval authorities as evidenced by correspondence from the Chief of the Bureau of Equipment to the Secretary of the Navy. This invited his attention to the matter and stated that he believed that all radio stations should be brought under some form of governmental regulation. He stressed the point that foreign governments were exercising careful supervision over such stations and recommended that action be taken by the Government to regulate the industry before vested interests became sufficiently entrenched to prevent such legislation.[7]

[6] Fayant, op. cit., p. 450.

[7] Letter, dated 10 Jan. 1902, Chief of the Bureau of Equipment to Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

In April 1902, Bradford continued to pursue the subject and addressed the Secretary of the Navy in reference to recent correspondence between the Navy and State Departments relative to desirable governmental control over radio stations established within the territorial limits of the United States. He urged that the Treasury Department be requested not to grant private individuals or corporations, the use of any of the lighthouses or lightships, or any portion of the reservations under its control for the establishment of private radio stations. In this connection, he advised that the Marconi Co. had established and was operating a station on the New South Shoals Lightship for the New York Herald. Continuing, he pointed out that the commanding positions generally occupied by lighthouses and lightships made them especially well adapted for such use, and that they would be required in any well-devised scheme of a national coast signal system. These considerations, and the fact that rights once obtained are very difficult to annul, and the further fact that such stations once established could monopolize the ether for purposes of radio transmission for many miles in all directions, made it necessary for the Bureau to make the request.[8]

The 15 September 1902 issue of the Army and Navy Journal contains this editorial:

> Admiral Bradford's plea for government control over all wireless station loses none of its force. In time of war such control would be almost indispensible to the safety of our squadrons at sea. It seems morally certain that wireless is destined to play a part of increasing importance in naval operations from this time forward. That being conceded, ordinary pruduence requires that the Government shall possess the right to exercise absolute control over all wireless stations on our coasts in time of national peril.

Another ardent supporter for naval control of the radio stations along our coast was Rear Adm. Bowman H. McCalla, U.S.N., Commandant of the Navy Yard and Station, Mare Island, Cal. In a letter, "Regarding Wireless Telegraph Stations," he presented some interesting points and suggested the matter be settled at the earliest moment because of the generally unsettled conditions in Asia and Europe. To him, it was quite clear that neither the Weather Service of the Agriculture Department nor the War Department were prepared to exercise the necessary control. Assuming that in time of war, the radio stations on our coasts would only be needed for communication with our ships of war, those of our possible allies, or vessels of the merchant marine, he recommended that as a maxim of war, naval messages should not pass through the hands of representatives of other departments. Referring to the disagreements which an unsatisfactory state of communications on the south coast of Cuba had engendered between the Army and Navy, he added that he felt it was his duty to call attention to the above-mentioned facts in order that cooperation between Army and Navy might be established without doubt.[9]

OBJECTIONS TO MONOPOLY

The success the Marconi interests were having in their efforts to establish a global monopoly of radio communications began to cause considerable concern among some of the world powers and especially in Germany.[10] In commenting upon the sentiment at the time, Barber reported:

> The Germans are wild over the Marconi monopoly. Such a monopoly will be worse than the English submarine cable monopoly which all Europe is groaning under and I hope the Navy Department

[8] Letter, dated 8 April 1902, Chief of the Bureau of Equipment to Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[9] Letter, dated 14 May 1902, Commandant Navy Yard and Station, Mare Island, Calif., to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[10] It is not intended to imply that the German Government would not have supported a global monopoly had it been possible for German industry to have established it.

of the United States will not get caught in its meshes.[11]

Early in 1902 an incident occurred which caused the German Government to take official cognizance of the situation. Prince Henry of Prussia, brother of the German Kaiser, was returning to Germany, in the S.S. *Deutschland,* after a visit to the United States. Soon after sailing, he desired to send President Roosevelt a radio message thanking him for the numerous honors and courtesies which had been accorded him.[12] The *Deutschland* transmitted this message to the Marconi station at Nantucket, but that station refused to accept it because the ship was fitted with Slaby-Arco radio equipment. The irate Prince brought the matter to the attention of his brother. Kaiser Wilhelm thereupon instructed his government to initiate action in an attempt to establish international control over radio communications.[13]

The German Government shortly thereafter dispatched notes to several governments, the United States included, pointing out that the Marconi interests were endeavoring to monopolize the transmission of messages and news by radio, and proposed the holding of an International Conference for the purpose of considering an International Convention for the regulation of radio telegraphy between ships at sea and ships and shore stations.[14]

Upon its receipt the German note was forwarded to the Navy Department for comment. On 8 April 1902, the Bureau of Equipment advised the Secretary of the Navy of its position:

The Bureau concurs in the opinion of the German Ambassador that any monopoly such as aspired to by the English Marconi Company in its supposed arrangement with the British Lloyd Company for the transmission of wireless telegraphic messages would hamper the development of other systems of wireless telegraphy not similar to that of the Marconi Company. The Bureau further believes that such monopoly once established would be injurious to the best interests of the country, and therefore agrees in the desirability of an international understanding whereby all systems of wireless telegraphy would be placed on the same level.

Inasmuch as in the present state of the development of wireless telegraphy, any station with sufficiently powerful transmitting apparatus to prevent messages being received within a considerable radius while it cannot insure non interference with its own messages by a rival station, the Bureau would respectfully urge on the Department, the desirability of such action by the government as would prevent the installation and operation within the territory of the United States or its dependencies of any wireless telegraphic apparatus except under such conditions as would insure harmonious working between it and neighboring installations whether of the same or rival ownership and under such governmental supervision as to preserve the best interests of the country.

In connection herewith the Department's attention is respectfully invited to the Bureau's letter No. 53467, of January 10, 1902, and its endorsement No. 55649 of March 10, 1902, on a letter from the Governor of Massachusetts to the Secretary, stating that he had no authority over the Marconi apparatus installed at Cape Cod.[15]

At the time arrangements were being made for an international conference, Kaiser Wilhelm was visiting the King of Italy. He met Marconi and brought up the subject with the remark, "Signor Marconi, you must not think that I have any animosity against yourself, but I do object to the policy of your company." [16]

THE FIRST INTERNATIONAL RADIO TELEGRAPHIC CONFERENCE, BERLIN, 1903

The endeavors of the German Government were fruitful. The First International

[11] Letter, dated 6 Dec. 1901, Cmdr. F. M. Barber, USN, (retired) to Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington ton, D.C.

[12] Letter, dated 3 July 1902, the Secretary of Navy to the Secretary of State, files, Bureau of Equipment, National Archives, Washington, D.C.

[13] Scientific American, 17 Aug. 1903, (Munn and Co., N.Y.).

[14] H. Cuthbert Hall, paper, "The Marconi System and the Berlin Conference," files, Bureau of Equipment, National Archives, Washington, D.C.

[15] Letter, dated 3 July 1902, the Secretary of Navy, to the Secretary of State, files, Bureau of Equipment, National Archives, Washington, D.C.

[16] Bernard Louis Jacob and D. M. B. Collier, "Marconi, Master of Space" (Hutchinson & Co., London, 1935.), p. 18.

Radio Telegraphic Conference assembled in Berlin on 4 August 1903. The governments of Germany, Great Britain, France, Russia, Austria-Hungary, Italy, Spain, and the United States participated. The American delegates were Brig. Gen. A. W. Greely, U.S.A.; Com. F. M. Barber, U.S.N. (retired), and Mr. John I. Waterbury of the Department of Labor and Commerce.[17]

Great Britain's delegates had been instructed to maintain an attitude of reserve, since under existing British law, that government was unable to impose regulations on communications except when they were confined within the territorial perimeter. The American delegates were contrarily instructed in that they were advised that the U.S. Government had absolute authority to impose controls upon any operator of any station which transmitted messages between States of the Union or with foreign countries, since the Supreme Court of the United States had rendered a decision that such transmissions were in the nature of commerce, and therefore within the plenary and paramount authority of the Federal Government to regulate, whether it be foreign or interstate.[18]

The conference was opened with an address of welcome by the secretary of state of the postal department of the German Empire. The assistant secretary of state of the German postal department, Sydow, head of the German delegation, was elected to preside over the Conference. In his opening speech, he urged that in the interest of the world's shipping, there should be inter-communication between all systems of radio telegraphy and that any radio station should be compelled to accept messages from any ship, irrespective of the equipment employed.[19] Due largely to Sydow's ability in humoring the varied interests and his admirable tact and judgement, a protocol [20] was prepared in an extremely short period of time. Although the delegates of Great Britain and Italy, the Marconi strongholds, could not concur with this protocol, all agreed to submit it to their respective governments as the basis of a future international convention to be adopted by a convention to be held the following year.

CONFLICT OF INTERESTS

In late 1903 there were 75 commercial stations constructed, under construction, or for which sites had been bought or sought for construction by the following firms: Marconi Wireless Telegraph Co. of America, De Forest Wireless Telegraph Co., the International Telegraph Co., and the National Electric Signaling Co. Over half of these were already equipped and operating and of such concentration and power as to present an actual problem.[21] Meanwhile, the Department of Agriculture, which had conducted experiments of considerable scope under the personal direction of Fessenden until August 1902, had in early 1904, directed an expansion of its radio system for meteorological reporting. The Department of War was expanding its system, and the Navy Department had established 20 shore stations and had plans for more than doubling this number during 1904. Not one of these departments was coordinating its work with the other de-

[17] Letter, dated 14 Aug. 1908, American delegates to the International Conference on Wireless Telegraphy, Berlin, to the Secretary of State, files, Bureau of Equipment, National Archives, Washington, D.C.

[18] Letter, dated 17 Nov. 1906, Ambassador C. Tower to the Secretary of State, files, Bureau of Equipment, National Archives, Washington, D.C.

[19] Letter, dated 14 Aug. 1903, American delegates, International Conference on Wireless Telegraphy, Berlin, to the Secretary of State, files, Bureau of Equipment, National Archives, Washington, D.C.

[20] The protocol drafted at this Conference has remained the basic portion of international radio agreements. For this reason it is reproduced as appendix B.

[21] Letter, dated 26 Aug. 1903, senior member, Wireless Telegraph Board to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

partments. In several instances they were endeavoring to install stations on the same Government reservations.[22]

In a letter of 7 March 1904, addressed to the Secretary of the Navy, via the General Board, Rear Adm. George A. Converse, U.S.N., the new Chief of the Bureau of Equipment, recommended that the Navy Department consider requesting the President to issue an Executive order placing all radio stations belonging to the Government on or near the coast, under naval control. The same letter also recommended that legislation be sought for the control or abolition of private radio stations on the coast. The following portions of this correspondence well illustrate the confused situation and the necessity for action:

With a comprehensive scheme of stations laid out the Bureau thinks that a foothold should be obtained without unnecessary delay so as to prevent priority of right to certain desirable locations being acquired by other departments, private corporations and individuals. On account of the principle defect of wireless telegraphy, i.e. liability of interference, this may become a very important consideration. The Bureau has already encountered serious trouble due to interference which at times seems to be malicious in the vicinity of New York. The station at the Boston Yard is within the range of private stations which can seriously interfere with it. A report from the Commandant of the Naval Station, Key West, received today states that a private station is being erected about a mile from the station at that place which will have sufficient power to seriously interfere with communication between Key West, Dry Tortugas, ships and Bahia Honda (should the Department erect a wireless telegraph station and when the coal depot is established). Other private stations with power of interference with naval wireless telegraph stations will probably soon be established unless some legislation is enacted to prevent it. Of course the Government can control private stations in time of war by exercise of martial law but probably at considerable expense for damages to the interests involved. Some legislation to control interference from them in times of peace is of growing importance and ought to receive early consideration.

Owing to the fact that the principal use to which wireless telegraph is likely to be put for many years is connected with the sea and account of the confusion that may arise from numerous independent stations being established in the same locality, the Bureau is of the opinion that it would be advisable to put all government wireless-telegraph stations on or very near our seacoast under the Navy Department and perhaps to have the Government take control of the entire wireless-telegraph service along the coast as some foreign governments do with the land-telegraph service.[23]

In support of his recommendations, Converse pointed out the difficulties the Navy was having in establishing its shore radio system. In 1902, the Bureau had begun the establishment of stations at Mare Island and on Yerba Buena Island, in San Francisco Bay, and to negotiate for a site at Point Bonita, on the military reservation at the entrance of that bay. After correspondence lasting over a year, it had abandoned the idea because the Army was insistent upon establishing a station there. The Bureau then considered the possibility of erecting a station on South Farollone Island off the entrance to San Francisco Bay. This idea was also abandoned, because the Department of Agriculture had erected a station there and it was considered undesirable for another one to be established near it. As a result, the Navy Department, which was most dependent upon radio, was placed in a position of dependence upon stations operated by men not under its control for the transmission of messages between its ships at sea when beyond the range of the station on Yerba Buena Island.[24]

Despite the Navy Department's increasing concern, the Government continued to delay taking action to regulate the use of radio. Meanwhile several instances occurred which tended to awaken public opinion. The first of these, previously mentioned, was the "failure" of radio during the International Yacht Races in the fall of 1901 which, in the eyes of the public, not only discredited all the systems involved, but what is much worse, discredited

[22] Electrical World and Engineer, 11 June 1904, p. 1114.

[23] Letter, dated 7 Mar. 1904, Chief of the Bureau of Equipment to the Secretary of Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[24] Ibid.

radio telegraphy as a whole. Moreover, the mercenary side of the radio telegraph movement had been made so unduly prominent, the self-advertising which had accompanied the development, had been so unblushing, and the squabbles between rival concerns so undignified, that the subject of radio telegraph as presented, particularly in the press, had well-nigh degenerated to a public nuisance.[25]

In January 1904, the London Times, with the consent of the Japanese Government, dispatched Colonel James, one of its leading correspondents, to the Russo-Japanese war theater with radio equipment to provide that paper and the New York Times with first-hand news of hostilities.[26] This action caused the Russian Government to issue notes of protest to the British and American Governments. This was discussed by President Roosevelt's Cabinet on 15 April 1904.

Faced with the increasing indignation of the public created by the quarrels among the commercial radio firms, the Russian ukase, the lack of coordination between the several departments of the executive branch of our Government, and the indication of the probable intent of Congress to deal with the situation at its next session, the Cabinet, at its meeting of 19 April 1904, reached an agreement on the desirability of the Government establishing general supervisory control over the operations of radio during peace and absolute control in time of war.

The Secretary of Agriculture then forwarded a memorandum to the President, via the Secretary of War, expressing his views as to the capabilities of his Department operating the Government radio stations along the coasts. In forwarding this, the Secretary of War advocated a joint Army-Navy recordkeeping in peacetime with the Navy Department assuming full control in wartime. President Roosevelt had, in the meantime, forwarded a copy of the Secretary of Agriculture's memorandum to the Secrtary of the Navy for comments by the Navy General Board. After considerable deliberation by its members, Adm. George Dewey, President of the Navy General Board, forwarded the opinions and recommendations of his associates:

The following facts must, in the opinion of the General Board, form the basis of the decision:

The principal defect of wireless telegraphy, the liability to interference, renders some central control indispensable to the integrity and effectiveness of any wireless-telegraph station. Without control over the placing of other stations, any wireless-telegraph station may be rendered absolutely useless either by accident or design.

The control of all wireless-telegraph stations belonging to the Government can be accomplished by Executive order. In order to control private stations, general legislation by Congress will be required, both because wireless telegraphy bridges the boundaries between States and because it stretches beyond the territorial limits of the Nation.

The principal use of wireless telegraph is now, and long will be, at sea—between ship and ship, or ship and shore. On shore other means of communication always exist, often better, always possible substitutes. The common telegraph or telephone, or the heliograph, permanent or portable, is everywhere available to the soldier or the meterologist. Permanent outlying stations can be connected by submarine cables. Although wireless telegraphy may be an added convenience, on shore it never can be indispensible. But from ships at sea, out of sight of flags or lights, and beyond the sound of guns, the electric wave, projected through space, invisible and inaudible, can alone convey the distant message.

In the present state of the science, development and experiment must be carried on largely at sea. We know as yet little of the limitations or possibilities of marine and transmarine communication. The Navy is the only department of the Government that has facilities for this branch of work, and irrespective of what is done by other departments, the Navy must, in its own interest, continue to experiment and to communicate between its ships and the shore.

To the Navy wireless telegraphy is absolutely essential. All the battleships and larger cruisers, perhaps even torpedo boats, are or will be equipped with it—as foreign navies are—to communicate with each other, as well as with the shore.

The Navy has already 20 wireless-telegraph stations on the seacoast and proposes to establish no less than 60 more. The Navy has already made arrangements to receive at its stations and to transmit over the land telegraph lines wireless messages

[25] Electrical World and Engineer, Jan. 2 1904, pp. 3–4.

[26] Samuel Lubell, "The Magnificent Failure," Saturday Evening Post, 17 Jan. 1942.

from passing merchant vessels. The Army has two stations in use in Alaska, and two others for experimenting, and has considered placing one at the Golden Gate on the Pacific coast. The Weather Bureau has two stations and proposes to erect seven more. All these stations, except the two in Alaska, which are for communicating with each other, are for the purpose of communicating between ships at sea, or in a few cases outlying islands and the mainland. Several of the Army and Weather Bureau stations interfere, or will interfere, with those of the Navy.

From these facts it appears clear that it would be in the interest of all to put the seacoast wireless-telegraph stations belonging to the Government under the control of one department. That control must extend to the determination of sites, and probably to the choice of systems, in order to prevent the several departments from frustrating one another's efforts. It does not seem to the General Board that there will be much difference of opinion on this question.

It remains to consider which department can best exercise control. For the reasons given—that the Navy has the preponderant interest in wireless telegraphy, that to the Navy it is indispensable, to other Departments merely accessory; that the Navy alone has facilities for experimenting with seacoast stations, and what ever other departments do, the Navy must continue to experiment; that the Navy already has five times as many seacoast stations as all other departments of the Government together—for all these reasons, the General Board is of the opinion that the Navy should exercise such control over the placing of all Government seacoast wireless-telegraph stations as to prevent their mutual interference. It is better and simpler for the department that has the predominating interest, even if it does not actually operate all the Government stations, to control their positions, rather than to attempt to exercise control by mutual agreements.

But if more than one Department is to operate wireless-telegraph stations on the seacoast, duplication and interference are inevitable. The two existing wireless telegraph stations of the Weather Bureau and the one proposed by the Army prevented the Navy from establishing its own station in the best place to communicate between ships at sea and the principal navy yard on the Pacific coast. Several of the new stations proposed by the Weather Bureau are on sites already occupied by the Navy, or within their range of interference; and all the rest would clash with stations projected by the Navy. A promontory best for the Weather Bureau is likely to be best for the Navy. For the purpose of receiving wireless telegrams from the ships at sea, the same seacoast station serves the need of all concerned. Obviously then, it is more economical that the department that controls the placing of all Government seacoast wireless-telegraph stations should operate them all.

It would, in the opinion of the General Board, be far easier for the Navy to transmit the messages of the Weather Bureau than vice versa. The seacoast wireless stations of the Weather Bureau are now but a 10th, and with the new stations planned will still be less than half, as many as the Navy has already. Granting that the Weather Bureau would be willing, as the Secretary of Agriculture says, to establish the greater number of additional seacoast stations needed by the Navy, and that there are still two important reasons why the Navy cannot depend, either in peace or war, upon stations controlled by the Weather Bureau:

It is absolutely necessary in time of war that the observers stationed to receive messages from the fleet should be subject to military law—that is, enlisted men of the Navy. Civilian marine observers, however, skillful in reporting merchant ships, could not so well be trusted to distinguish the wireless messages of friendly from hostile men-of-war, or to transmit accurately technical naval signals, and could not be trusted at all with the secret signal codes of the Navy. Whoever mans the seacoast in time of peace, the Navy must man them in time of war.

Unless the Navy mans the stations in time of peace it will not have the trained force ready to man them in time of war. Practice with instruments on shipboard alone will not suffice. The man to be trusted at a seacoast station in time of war, alert to detect the unexpected, must be familiar with the usual local business in time of peace. The opportunity for training the signalmen is no less important than testing the apparatus.

The single instance cited by the Secretary of Agriculture of the weather observer at Jupiter Inlet reporting what he saw and having the good fortune to be the first to see the arrival of the *Oregon* is far from proving that the Navy can trust to anyone but its own trained men to receive wireless signals from ships at sea. From every point of view, therefore, it appears to the General Board that the seacoast wireless-telegraph stations of the Government are essential to the Navy and to no other department; and the General Board therefore concurs in the recommendation of the Chief of the Bureau of Equipment that an Executive order be issued placing them all under naval control, to be manned and operated by the Navy.

The subject of legislation to control private wireless telegraph stations on the seacoast is of growing importance to the Government because of the increase in the number of them and their liability to interfere, maliciously or accidentally, with the Government's stations. In order to safeguard its own interest, both in peace and war, the Government must have some means to prevent the erection of a private wireless-telegraph station within the range of interference of one of its own. It would not be wise in the opinion of the General Board, for the Government to undertake to manage all the seacoast wireless-telegraph business of the country, nor for an industry of such growing commercial utility to be controlled directly by a military branch of the Government. The Department of Commerce and Labor, now charged with the administration of the Lighthouse Service, the Coast Survey, the inspection of steamboats, and the jurisdiction over merchant shipping generally, would perhaps be the most natural ones to control private wireless-telegraph companies. The law should clearly give the Government priority of right and prohibit the erection of any private station without the approval of the Government.[27]

In forwarding the comments of the General Board to the President, Navy Secretary William H. Moody suggested that it appeared that economy and good administration would forbid duplication of such an activity as radio therefore the control over all Government radio should be vested in one department, whose facilities would serve all Government users. If it be conceded that the control of radio should be vested in a single department, it seemed clear that it should be the Navy Department, for reasons so obvious that they required no restatement.[28]

THE ROOSEVELT BOARD

Acting upon a recommendation of his Navy Secretary, the President, on 24 June 1904, appointed Rear Adm. Robley D. Evans, USN, then chairman, U.S. Lighthouse Board, Department of Commerce and Labor; Rear Adm. Henry M. Manney, USN, Chief of the Bureau of Equipment; Brig. Gen. A. W. Greely, Chief Signal Officer, USA; Lt. Comd. Joseph L. Jayne, USN, head of the Radio Division, Bureau of Equipment; and Prof. Willis L. Moore, Weather Bureau, Department of Agriculture, as members of a board to consider the entire question of radio in the service of the national Government. At the same time all previous correspondence on the subject was forwarded to this Board.[29]

The Interdepartmental Board of Wireless Telegraphy, generally known as the Roosevelt Board, began its deliberations on 6 July. Commenting on the progress made by it during its first few meetings, one member is reported to have remarked:

We met yesterday, today, and will meet tomorrow. We have taken a most solemn oath not to divulge the slightest word concerning our proceedings and to tell the truth I could not break this oath if I tried for the very reason that we have not done a thing.[30]

In its editorial column the same periodical which printed the above, ventured the following opinion:

With each department of the government working independently upon this problem of wireless-telegraphy and apparently jealous of anything accomplished in the same line by another department it is difficult to see anything but a future filled with strife and bickering for the special commission of the President's. The situation is further complicated by the wireless companies themselves, which, not content with every-day competition, have carried, in at least one instance, their troubles to court.[31]

Despite pessimistic expressions, the Board not only reached conclusions and arrived at recommendations, they did it in unanimity. Its recommendations, insofar as they pertained to the Government's use of radio, were adopted, and they exercised a profound influence on the future of radio in the United States. The dominance of the Navy in this field was established and it was enabled to launch its own radio system, one for which Congress saw fit to appropriate many millions in the following years. It has been stated, "In few fields

[27] Wireless Telegraphy, "Report of the Interdepartmental Board Appointed by the President to Consider the Entire Question of Wireless Telegraphy in the Service of the National Government," (Government Printing Office, Washington, D.C. 1905).

[28] Letter, dated 18 June, from the Secretary of Navy to the President of the United States, files, Bureau of Equipment, National Archives, Washington, D.C.

[29] Letter, dated 24 June 1904, Secretary to the President to Chairman of the Lighthouse Board, Department of Commerce and Labor, files, Bureau of Equipment, National Archives, Washington, D.C.

[30] Army and Navy Journal, 9 July 1904, (Army and Navy Journal, Inc., Washington, D.C.), p. 1173.

[31] Ibid., p. 1173.

of national endeavor have public funds been expended more wisely than in developing the wireless arm of the Navy." [32]

Not only was the Board's action of momentous import to the Navy, but as will be demonstrated hereafter, radio and its future offspring owe an everlasting debt to this arm of the services for its aid and contribution in the advance of the art. Not only have the contributions of Navy scientists and technicians been outstanding and numerous, but what is probably equally as important, is that service's continued patronage of promising private inventors and the laboratories of commercial organizations.

The report of the Interdepartmental Board of Wireless Telegraphy was submitted to the President on 12 July 1904. Its recommendations constitute the first well-defined radio policy of the United States Government. In brief these are:

(a) The Navy be designated to provide efficient coastwise radio communications for the United States Government and when not in competition with commercial stations to receive and transmit all radio messages to and from ships at sea.

(b) The Army be authorized to erect such stations as deemed necessary provided they do not interfere with the coast wise radio system of the Government under control of the Navy Department.

(c) Legislation to prevent the control of radio telegraphy by monopolies or trusts should place supervision in the Department of Commerce and Labor.[33]

MARCONI INTERESTS VOICE OBJECTIONS

Before President Roosevelt could take final action on the report of his board he received a letter from the law firm of Betts, Betts, Sheffield and Betts, legal representatives of the Marconi Wireless Telegraph Co. of America, protesting an order of the Department of Commerce and Labor to remove the Marconi apparatus installed in the Nantucket Shoals Lightship for the New York Herald in 1901. This action had been taken in order that the Navy might install a station on the lightship. This letter and its appendices attempted to point out the consequences of such action. It stated that "efficient communications cannot be established between two wireless telegraph stations equipped with apparatus of different design without reducing enormously the scope and utility of the more advanced system," and "even if technically possible would impose upon the Government the necessity either to accept money for the service or to transmit messages without cost, in direct competition with commercial organizations whose business it is to transmit such messages . . . This would seem to be not in accord with the generally accepted policy of the Government." [34]

On 21 July 1904 the President forwarded the Sheffield letter to the Senior Member of his Board with the following instructions:

I have read with great interest the report of your Inter-Departmental board. Before taking action on it, I should like the comment of the Board upon the enclosed letter from Mr. James R. Sheffield regarding the Marconi matter. You can either reconvene the Board or write your own comment and have it submitted to the members of the Board for such expressions as they may desire to make.[35]

The Board reconvened and concluded that, under the circumstances, it would be a great mistake to allow the Marconi station to continue to operate in the lightship as it was stationed in a position of great importance, both to the Navy and to commerce. Since the Marconi Co. refused to transmit messages from ships using equipments of other manufacture, its use of the lightship would amount to giving the Mar-

[32] Gleason L. Archer, "History of Radio to 1926," (The American Historical Society, Inc. 1938.), p. 76.

[33] The approved recommendations of the Roosevelt Board formed the Government's policy in the use of radio for almost two decades. For this reason it is reproduced as appendix C.

[34] Letter, dated 19 July 1904, James R. Sheffield to President Roosevelt. Wireless Telegraphy, op. cit., pp. 26–27.

[35] Wireless Telegraphy, op. cit., p. 25.

coni Co. powerful governmental aid in its effort to maintain a monopoly.[36]

The Board further noted:

> Learning that there was some probability that the *Herald* station on the lightship would be discontinued as a result of the complaint of the German Ambassador, the Bureau of Equipment, Navy Department, requested permission to establish a station there having for its object, service in connection with ships of the Navy, the transmission of news of interest to the merchant marine, and transmission of wireless messages received from ships engaged with any system whatever. Permission was granted and the apparatus will probably be installed by the middle of August. It is intended to make Newport the shore connection, and the distance covered will be about double that between the lightship and the Marconi station on Nantucket Island.[37]

Refuting the Marconi contention that communications were unsatisfactory between equipments of different manufacture, the Board made the observation that the Navy had communicated most satisfactorily between stations equipped with the Slaby-Arco apparatus and one with a combination of other makes, stating that in tests in the vicinity of New York, conducted by the Navy Department, no difficulty was experienced in communicating between equipments of different manufacture. Concerning the problem of charges for services, the Board stated it could see no objection to a reasonable charge being made for service. It did not consider that competition would exist between a department of the Government and private companies. It felt Mr. Sheffield had confused Government competition with Government action which permits of private competition, and that the Marconi Co.'s adamant refusal to receive messages at any of its stations from other than Marconi-equipped stations, was a strong argument in favor of Government supervision of private stations.[38]

On 29 July 1904 President Roosevelt approved the recommendations of the Board, and directed that such recommendations as concerned the executive branch of the United States Government be effected immediately.

THE BEGINNING OF THE STRUGGLE OF VESTED RADIO INTERESTS TO PREVENT LEGISLATION TO CONTROL THEIR ACTIONS

The Navy's assumption of control of the Government radio system caused commercial interests to fear that the next step would be directed towards governmental control over their operations. Led by the Marconi interests they immediately launched a campaign to defeat any such legislation which might be proposed.

When the Navy Department announced that the radio service between the Nantucket Shoals Lightship and Newport would be available to public use and opened to vessels equipped with apparatus of any make, the Marconi Wireless Telegraph Co. of America, in a series of letters during November 1904, was quick to inform the Bureau of Equipment that such service would be in direct competition with them and that they did not view this with favor. Also, as compared to them, whose experience was based on several years of operating a commercial system, comprised of about 100 stations, the Bureau could hardly claim any experience in commercial radio telegraphy. Their chain of communications already comprised shore stations of the British, Italian, Belgian, Canadian, Newfoundland, and other governments, plus Lloyds, and their own on shore stations, and ships of many nationalities, including American, British, German, French, Italian, Dutch, and Belgian.[39]

Since they had been deprived of the use of the Nantucket Shoals Lightship station,

[36] Wireless Telegraphy, op. cit., pp. 36–38. (Letter, dated 29 July 1904, Interdepartmental Board to President Roosevelt.)

[37] Ibid., p. 36.

[38] Ibid., p. 37.

[39] Letter, dated 28 Nov. 1904, Marconi Wireless Telegraph Co. of Amer. to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

they were extending the range of their Siasconset installation to communicate with Marconi-equipped vessels. The Marconi firm contended that their apparatus was removed from the lightship at the request of the German Ambassador on the grounds that messages from German ships equipped with German apparatus were not being accepted. The Navy Department was informed that the German equipment it had purchased infringed Marconi patents granted by the Government of the United States, and that it was efficient only in proportion to the degree of exactness with which Marconi devices had been copied. They considered the action of the Navy Department to be detrimental to commerce and therefore would have to refuse to allow vessels equipped with Marconi apparatus to communicate with the Government station at Nantucket.[40]

In another letter, dated 28 November 1904, the Marconi Co. berated the Navy because it would not accept the conditions it had proposed for the use of its equipment; namely, that if the apparatus were used for commercial purpose, it should be used in accordance with rules and regulations adopted by all the transatlantic liners equipped with radio and at the stations in different countries with which the steamers equipped with radio communicated, and that the commercial tolls should belong to the Marconi Co. A few days later the firm submitted a list of 12 shipping interests which it claimed had petitioned the Government not to remove the Marconi equipment from the lightship. This list included the Cunard, Hamburg-American, Cosmopolitan, Italian Royal, Mail, Neptune, Philadelphia Trans-Atlantic, and Insular Navigation Lines.[41] The reply of the Secretary of the Navy to the Marconi correspondence was to the effect that the radio service established by the Navy Department had the approval of the President, and that this approval was given after careful consideration of the report of the Interdepartmental Wireless Telegraph Board. The question of establishing a Government station on the Nantucket Shoal Lightship had been given special consideration by the President, after the Marconi Co.'s attorney had submitted arguments in favor of retaining the station operated by the Marconi Co. for the New York Herald. He ended, by stating, that in view of this he could see no reason for resubmitting the question to the President.[42]

Early in 1905, Mr. John D. Oppe, General Manager of the American Marconi Co., wrote a long letter [43] to Secretary Morton again belaboring him concerning his policies on radio communications. This was answered by the Secretary within the week by a letter [44] commenting upon each of Oppe's criticisms. The Secretary assured him that the Navy Department did not desire supreme jurisdiction, but only such legislation as was necessary "to protect its military interests by protecting its stations against noninterference, and to regulate intercourse between commercial wireless stations, especially those reaching out seaward beyond the frontiers of the country." He went on to stress that, in time of war, the Navy Department would not desire to be burdened with all the stations that may have come into being, and it wished only those necessary for use in the defense of the coast and the enactment of such legislation as would prevent their being interfered with. With commercial stations in various States near the coast interfering

[40] Ibid.

[41] Letter, dated 30 Nov. 1904, Marconi Wireless Telegraph Co. of America to the Secretary of Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[42] Letter, dated 4 Dec. 1904, Secretary of the Navy to Marconi Wireless Telegraph Co. of America, files, Bureau of Equipment, National Archives, Washington, D.C.

[43] Letter, dated 9 Jan. 1905, Mr. J. D. Oppe, General manager Marconi Wireless Telegraph Co. of America, to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[44] Letter, dated 17 Jan. 1905, Secretary of the Navy to the Marconi Wireless Telegraph Co. of America, files, Bureau of Equipment, National Archives, Washington, D.C.

with each other, both intentionally and unintentionally, and with State legislation unable to regulate interference from other States, it was absolutely necessary that some branch of the National Government have cognizance of interstate radio commerce and interference. Therefore, the Navy Department, because of its paramount military interest in radio, assumed the initiative in seeking governmental action. He stressed the point that the Navy Department had asked that the Department of Commerce and Labor be given entire control of the subject of commercial radio, with the single reservation that commercial stations would not be allowed to interfere with those of the Government, and it was to be expected that the Department of Commerce and Labor would perform that service in protecting the Government and dealing equitably with the commercial establishments.[45]

Mr. Oppe, in commenting upon a suggested issuing of licenses by the Department of Commerce and Labor, stated that it provided "no safeguard for the protection of any station." The Secretary replied, in effect, that the performance of its duties by that Department in the matter of the control of radio stations, was in keeping with the current work of that Department, and that it was preferable that such control and regulation as called for, be in the hands of a civil rather than a military department of the Government.[46]

In the same letter, Mr. Oppe deplored the fact that, in the Board's deliberations, "the very important question of patents has apparently been entirely disregarded." His letter went on to state that the patent laws had been made for the purpose of encouraging inventors and providing, for those who owned patents, security for their investments. Under ordinary circumstances the rights of the owners of radio patents could be upheld in the courts against persons who made a commercial use of their apparatus. Injunctions could be obtained restraining unauthorized infringements, and the full benefit from the commercial use of the devices restrained by the rightful holder of the patent. Such, however, they maintained "does not apply to the use of patented apparatus by the Government, as means have yet to be found for preventing the Government from using any apparatus made in infringement of patents or otherwise." This being the situation, if radio passed into the hands of the Government, the patents already granted by the United States would cease to be of value.[47]

Replying to the foregoing and the claim that the Marconi patents were being infringed by other companies, Secretary Morton answered the latter point first in observing that the contrary was stated with equal positiveness by representatives of other radio firms. As to the other point made, he brought out the Navy's position in regard to the patent problem, in pointing out that until the Marconi Co.'s patent rights were settled by the courts, the Navy Department should certainly be accorded the same freedom in the use of the various systems as would be accorded to an individual using them.[48]

The Navy Department did not concede the correctness of his conclusions concerning the patent situation. In contracting for radio appliances it had included in recent contracts a clause requiring the contractor to protect and defend the Government against claims for infringement of patent rights due to the use of any apparatus supplied under the contract. Only when the patentee was in the service of the Government at the time of making the invention, could the Government use a patent without the payment of royalty, and in case of violation of patent right by the Government, recourse could always be had to the courts.[49]

The Secretary again explained that the Navy's equipping the Nantucket Lightship

[45] Ibid.
[46] Ibid.
[47] Ibid.
[48] Ibid.
[49] Ibid.

was a perfectly legitimate action in the interests of commerce, since it was a public vessel, stationed off the shoals for the purpose of increasing the safety of navigation, and no commercial company was entitled to any place aboard her. To allow the occupation of a Government vessel by one commercial company would give a valid cause for complaints of injustices and favoritism by others. The fact that this ship was most favorably located for the financial advancement of the Marconi interests did not strengthen their claim.[50]

The Secretary's letter closed with the following paragraph:

> The Department is of the opinion that the statements contained in your letter are arguments in favor of the necessity of legislation with the object of regulating the wireless telegraph business of the coast.[51]

The American Marconi Co. was not alone in this fight against Government control. The National Electric Signaling Co., in a letter[52] to the President, stated that it was of the opinion that should legislation be enacted preventing the establishment of any radio station anywhere, either on the coast or inland, without first obtaining the consent of the Secretary of Commerce and Labor, it would result in only Government stations being permitted at points where stations are needed for marine service. This would further result in Government stations receiving and transmitting commercial radio messages free of charge. This would in effect amount to practical confiscation of all property rights in its inventions which the firm had obtained through the U.S. Patent Office. The National Electric Signaling Co. felt that the Board had based its report on the belief that one station would always interfere with another near it, and that without regulation the usefulness of the invention would be destroyed. It maintained, however, that such was not the case, as under Fessenden inventions, two or more stations could be used in close proximity without interference, as had been demonstrated to members of the Navy Wireless Telegraph Board who possessed knowledge of the effectiveness of the Fessenden inventions in eliminating interference, of secret sending and other claims. The company stated that it believed there should be no legislation regulating radio at the time, for when apparatus was used that embraced the most improved inventions, interference would be no factor. It further contended at the time it was easier to cause interference which would prevent communication over an ordinary telegraph or telephone line than it was to cause interference to a wireless station, yet the former were permitted to get along without special laws to prevent interference. The letter continued with belaborings, inferring that those who sought to control radio were lacking in understanding of the new science.

As to the matter of national defense, it was submitted that radio telegraphy should be on the same footing as cables. In case of war or other necessity, the company assumed that the Government would seize the radio stations as well as the cables, so that there would be no more necessity of controlling one in time of peace than the other. It asked to be allowed to develop its system commercially, unhampered by restrictive laws and in competition with the existing means of transmitting messages. Such, it maintained, would not interfere with the Navy Department erecting and operating its own stations and would not prevent them from using their own inventions.[53]

A "Memoranda on Conclusions of Interdepartmental Wireless Telegraph Board", prepared by the National Electric Signaling Co., noted a conclusion of that Board which stated that the science of radio telegraphy had been advanced by the able

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[50] Ibid.

[51] Ibid.

[52] Letter, dated 7 Oct. 1904, National Electric Signaling Co. to the President of the United States, files, Office of Naval Records and Library, National Archives, Washington, D.C.

[53] Ibid.

and consistent work of the Signal Corps, the Weather Bureau, and the Navy Department and claimed that this could be disputed. It maintained that the Signal Corps had appropriated features of different manufacturers and purchased some Fessenden liquid barretters from the De Forest Co., assembled them, and called it their own system. The Navy was accused of having purchased upwards of 100 Slaby-Arco equipments which infringed some of Fessenden's important patents. Both of the actions had been protested by the National Electric Signaling Co., which was powerless to do more. The "Memoranda" even went on to state that, "As a matter of fact, apparatus that does not infringe the Fessenden patents has never yet transmitted messages over twenty miles." [54]

Continuing, the memorandum noted that while radio telegraphy was of paramount interest to the Government, through the Navy Department, the company felt its importance for use in commerce on land and sea would be many times greater. Relative to the Board's conclusion that a complete coastwise system of radio telegraphy should be maintained by the Government, it maintained this to be purely a matter of policy. Since it did not do so in the case of telegraph, telephone, or cable, it was not necessary in this case, since private companies could probably do it more efficiently and cheaply.[55]

Subsequent to the report of the Interdepartmental Board, the subject of radio legislation was considered by the Navy Department and the Department of Commerce and Labor. In January 1905, the Secretary of the Navy transmitted to the Department of Commerce and Labor a memorandum, prepared by Admiral Manney, containing a proposed draft for this purpose. This was referred to a committee, which had already been appointed to consider the recommendations of the Interdepartmental Board and the position the United States should take on the protocol drawn up at the first International Radio Telegraph Conference. This committee consisted of Mr. James Randolph Oerfield, Commissioner of Corporations; Mr. Eugene T. Chamberlain, Commissioner of Navigation, and Admiral Uriel Sebree, USN, Naval Secretary of the Lighthouse Board. From the report of this committee, it appears that it had the assistance of Admiral Manney and Lt. Comdr. Joseph L. Jayne, and that meetings were held at which representatives of the Marconi, De Forest, and Fessenden interests appeared and stated their views with reference to the proposed supervision of radio by the Government. This proposed legislation was strenuously opposed by the Marconi and Fessenden firms and others, but some of the radio companies of the country believed it would be beneficial alike to both governmental and private interests. The committee submitted, with its report, a draft of a measure for the national supervision of radio which was offered and accepted as a substitute for the measure suggested by the Secretary of the Navy.[56]

The Navy Department and the Department of Commerce and Labor jointly transmitted this proposed measure to the War Department for comment, stating their intention of transmitting it to Congress for enactment into law, unless there were contrary reasons from the viewpoint of the War Department. The Chief Signal Officer of the Army submitted several comments but stated, "There is not special reason from the standpoint of the War Department, why the bill should not be enacted."

This proposed legislation was not transmitted to Congress because of the deter-

[54] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., "Memoranda on Conclusions of Interdepartmental Board on Wireless Telegraphy," files, National Electric Signaling Co.

[55] Ibid.

[56] Memorandum, "The International Wireless Telegraph Convention," concluded at Berlin, 3 Nov. 1906, submitted to the Senate Committee on Foreign Relations by the Army and Navy, files, Bureau of Equipment, National Archives, Washington, D.C. The proposed legislation is reproduced as appendix D.

mined opposition of vested interests and because the Second International Radio Telegraph Conference had been indefinitely postponed because of the war between Russia and Japan. Nevertheless it remained a live issue with the contending forces drawn up for a battle which would necessarily and inevitably take place.

CHAPTER VIII

Early Expansion of Naval Radio Communications

REVITALIZATION OF THE WIRELESS TELEGRAPH BOARD

By the beginning of 1904 all the radio equipment which the Navy had purchased had been installed. The assigned responsibility to provide radio communication service to the other Government departments necessitated considerable expansion and, in numerous cases, the establishment of circuits over distances not yet conquered. Politically, the international situation had deteriorated and our relationship with Germany was questionable.[1] As a country, the United States was becoming more and more self-sufficient from a manufacturing viewpoint, and with this there came a stronger feeling of nationalism.

There is nothing of record to indicate that a decision was reached to cease, if possible, the purchase of radio equipment from foreign countries. Such a decision would have been logical, for, under the existing circumstances, we were dependent upon Germany for the necessary spare parts for our radio equipment. In event of a war with Germany or with a country she favored, that supply could be cut off.

In its endeavor to secure equipment manufactured in this country the Navy Department on 2 April 1904 revitalized its Wireless Telegraph Board which had practically ceased to function after September 1903. The senior member and the member-recorder were assigned full-time duty with the Board, and the former was given the authority to convene the remaining members when and at such places as might be necessary.[2] The naval radio stations at the Highlands of Navesink, N.J., and the Navy Yard, Brooklyn, N.Y., were made available to the Board for conducting tests, and training vessels were made available to assist. The original instructions to the Board, except where inconsistent with special conditions, and augmented by instructions relative to interference, interception, secrecy of transmission, and compatibility with other systems, were to govern all tests.[3]

With the single exception of Jayne, Head of the Radio Division, Bureau of Equipment, new members were appointed to the Board. These were Capt. J. A. Rodgers, USN, senior member; Comdr. George H. Peters, USN, Superintendent of the Compass Office; Comdr. Bradley A. Fiske, USN, who had as a younger officer conducted

[1] In 1902 President Roosevelt mistakenly warned Germany that he would send an American fleet to Venezuela to prevent any violation of the Monroe Doctrine. In late 1903 occurred the Panamanian Revolution for which our Government was somewhat responsible. In the same year relations between Russia and Japan were near a breaking point. These deteriorated still further and resulted in war in 1904. In the same year, President Roosevelt notified France and Germany that, if they came to the aid of Russia, he would "promptly side with Japan and proceed to whatever length was necessary on her behalf" (David Sayville Muzzey, "A History of Our Country" (Ginn & Co., Boston, 1939), pp. 565-570.

[2] Letter, dated 16 Apr. 1904, Chief of the Bureau of Equipment to the Commandant, Navy Yard, New York, N.Y. files, Bureau of Equipment, National Archives, Washington, D.C.

[3] Letter, dated 18 Aug. 1902, Chief of the Bureau of Equipment to Comdr. Conway H. Arnold, USN, files, Bureau of Equipment, National Archives, Washington, D.C.

experiments with induction telegraphy; and Lt. Webster A. Edgar, USN, who was also the recorder. Chief Electrician's Mates Bell and Scanlin were assigned in charge of the Brooklyn Navy Yard and Highlands stations, respectively.[4]

Earlier, the Navy had purchased the equipments for the comparative tests. Beginning in 1904, the companies participating in tests were required to furnish, operate, and bear all expense except for electrical power. However, the tests were to be under the complete control of the Bureau of Equipment, with representatives of the companies privileged to be present at all times when their apparatus was being operated.[5]

Manufacturers were advised to inform the Bureau of Equipment should they desire to participate. The following firms or individuals expressed their desires to submit equipments: Messrs. Anders Bull, Charles S. Piggott, and James F. King, the Marconi Wireless Telegraph Co. of America, the National Electric Signaling Co. (Fessenden), the International Wireless Co. (Shoemaker), the De Forest Wireless Telegraph Co., the Telefunken Co. (Amalgamated Slaby-Arco and Braun-Siemens-Halske).[6]

FURTHER DISAGREEMENT WITH AMERICAN MARCONI

Despite the offer of the Marconi Co. to participate in the tests, when they were requested to provide equipment they interposed objections to having its efficiency judged by short-range tests and stated in a letter to the Bureau of Equipment:

> We are, however, not prepared to equip stations at our own expense for the purpose, of demonstrating our ability to communicate across 21 miles, unless under satisfactory contract; because we are doing commercial work at numerous stations in the United States over greater distances, and, as we are communicating regularly and reliably between Cape Cod and Cape Breton, over 800 miles, no outlay for the purpose of demonstrating only commends itself to us.[7]

They further stated that it was their desire to demonstrate reliable communications over great distances, under varying circumstances, and the working of several circuits simultaneously. They presented, as examples, the recent transatlantic voyages of the steamships *Lucania* and *Duncan*. The *Lucania* had recently received messages the entire voyage from either English or American stations. The *Duncan* had maintained continuous communication all the way to Gibraltar and while at anchor there.[8] Although these accomplishments were of interest to the Navy, it informed the Marconi Co. that the stations selected had been chosen because interference in the vicinity of New York City was probably greater than in any other locality, and that one of the objects of the test was to determine if any of the equipment would operate through interference, and, further, that it preferred to conduct tests in the manner presented, whatever the shortcomings of its modus operandi in the opinion of others. The Bureau further assured the Marconi Co. that, should it desire to enter the competition, it would be given the same opportunity as others to demonstrate its claims, there being no desire to discriminate in favor of anyone. They were advised that after the New York Navy Yard-Nave-

[4] Letter, dated 16 Apr. 1904, Chief of the Bureau of Equipment to Capt. John A. Rodgers, USN, Senior Member, Wireless Telegraph Board, files, Bureau of Equipment, National Archives, Washington, D.C.

[5] Letter, dated 2 Apr. 1904, Chief of the Bureau of Equipment to Capt. John A. Rodgers, USN, "Conditions Governing Tests of Wireless Telegraph Apparatus Carried on Between the Naval Wireless Telegraph Station at Navesink, N.J., and the New York Navy Yard," files, Bureau of Equipment, National Archives, Washington, D.C.

[6] The German Kaiser, in 1903, directed the amalgamation of the Slaby-Arco and Braun-Siemens-Halske Companies. The new company, Gesellschaft für Drathtlose Telegraphic, became commonly known as Telefunken.

[7] Letter, dated 2 May 1904, Marconi Wireless Telegraph Co. of America to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[8] Ibid.

sink tests it was planned to carry out distance tests between ships and shore stations. In further correspondence, the Bureau of Equipment intimated that nonparticipation in the competition by the Marconi Co. might place them in the position of being open to the suspicion that they feared to compete with other manufacturers of radio apparatus under the prevailing intereference conditions in the vicinity of New York.[9]

In reply the Marconi Co. stipulated that, prior to undertaking any tests for the U.S. Navy, it required the assurance that successful performance would result in a pecuniary reward proportionate to the service rendered. The same letter contained a veiled warning, which stated that the company was aware that several other "so-called systems," exploited by persons who had, in varying degrees of exactness, copied Marconi apparatus, were claiming the attention of the Bureau. The Marconi interests considered that the Navy should be advised that they had already commenced an action of infringement of patents against the manufacturers of one of these "so-called systems." [10] The Bureau of Equipment, in reply, stated that it did not propose to enter into any contingent contract prior to the tests.[11]

The American Marconi Co. replied to this by reverting to their old contract procedures and informed the Bureau that it was prepared to contract with the Navy for the use of its system under the following terms:

That the Bureau shall be entitled to use apparatus of the Marconi system having a maximum range of 240 miles, for naval stations on shore in the United States of America and dependencies, and on board U.S. vessels, at a yearly royalty of $50,000 per annum; which annual royalty shall entitle the Bureau for the duration of this contract to the use of all the Marconi apparatus and inventions now in use or which may be acquired later, applicable to such stations.

That the Bureau will install apparatus of the Marconi system at their stations, paying therefore the current market price—it being understood that the royalty mentioned above shall cover all claims by the Marconi Co. for royalty on apparatus installed by the Bureau.

That the Bureau will, as far as may be possible, agree to accept messages from vessels equipped with Marconi apparatus and will make such arrangements at naval stations as will:

(a) Enable intercommunication with vessels of the mercantile marine equipped with the Marconi system.

(b) Prevent the interference with vessels of the mercantile marine equipped with the Marconi system when communicating with naval vessels.

That the Marconi Co. agrees to give the Bureau certain preferential rights in the dispatch of naval messages over ordinary messages from their commercial stations now existing or established in the future, which shall, at the convenience of the Marconi Co. remain in operation for the benefit of the Marconi Co.

That the Bureau shall use such powers as they may have, from time to time, to prevent the interference by other systems with Marconi commercial stations and with naval stations, working together or independently.

Except in time of either emergency, or war, or in the case of war vessels, the Bureau shall not use the Marconi Wireless apparatus fitted at their stations for the interchange of signals with vessels or stations not equipped with apparatus provided by the Marconi Co.

That the Bureau shall have the use of a long-distance station, (which term is understood to mean—a station capable of transmitting a message 500 miles and upwards to vessels fitted with suitable receivers) at certain periods on certain terms.

That the period of the contract shall be for a number of years which will be determined after consultation with the Bureau. [12]

The Bureau's reaction to this proposal was decidedly unfavorable, so Marconi officials next addressed an 11-page letter to the Secretary of the Navy, discussing radiotelegraphy from the points of view of the

[9] Letter, dated 4 May 1904, Chief of the Bureau of Equipment to the Marconi Wireless Telegraph Co. of America, files, Bureau of Equipment, National Archives, Washington, D.C.

[10]-Letter, dated 18 May 1904, Marconi Wireless Telegraph Co. of America to the Chief of the Bureau of Equipment, files Bureau of Equipment, National Archives, Washington, D.C.

[11] Letter, dated 4 May 1904, from Chief of the Bureau of Equipment to the Marconi Wireless Telegraph Co. of America, files, Bureau of Equipment, National Archives, Washington, D.C.

[12] Letter, dated 21 June 1904, Marconi Wireless Telegraph Co. of America to Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

Navy alone, and of the mutual relations of naval and commercial interests, and concluded by stressing why the Marconi system should be adopted.[13] This the Bureau considered an "audacious attempt to induce the Government to participate in a monopoly calculated to extinguish other systems, some of which are more promising than the Marconi." Further, the Bureau reiterated the opinion that no radio-telegraph station should be allowed to be established on the coast of the United States which would not receive messages from any properly tuned ship's apparatus, whatever the system.[14]

Thus, the Marconi Wireless Telegraph Co. of America effectively eliminated the possibility of early use of its equipment by the branch of the Federal Government which had been assigned the primary governmental responsibility in this field. This condition continued to exist until 1906, when that company, realizing that the Navy would not be a party to the establishment of a radio monopoly, and especially not to a company under the domination of foreign interests, abandoned their policy and offered the outright sale of its equipment.

TESTS OF ANDERS BULL EQUIPMENT

The March 1903 issue of Scientific American contains an article by Mr. A. Frederick Collins on the Bull system of wireless telegraphy which describes the system and concludes with the following paragraph:

> This is the first time in the history of wireless telegraphy that three messages have been transmitted and received simultaneously and selectively and it is also the first time in the history of the art that mechanical methods have been successfully employed in obtaining selectivity. The sending and receiving instruments may be set up at different points and at varying distances, which is a decided advantage over those systems based on pure electrical resonance.

When brought to their attention, this article evoked considerable interest from the members of the Wireless Telegraph Board. Mr. Anders Bull, of Christiania, Norway, had through his American representative, Mr. O. L. Nichols, of Coudersport, Pa., offered his equipment for tests. The Board accepted this offer and arrangements were concluded for the tests, which began on 12 May 1904. Bull termed his transmitter a "dispenser" and his receiver a "collector." The unique feature of the system was the use of synchronized disks in the "dispenser" and "collector" which controlled the periodicity and length of the emitted waves. During the tests messages were successfully transmitted and recorded, the maximum speed being seven words per minute and the average six. A Morse recorder attached directly to the relay actuating the synchronized portion of the "collector" indicated that a message sent by the "dispenser" could not be intelligently received without the use of the complete "collector." Tests were made to determine the degree of synchronization required. With the "collector" speed varying from 3½ r.p.m. slower to 3¾ r.p.m. higher than the "dispenser" speed, accuracy or reception was not impaired. Tests were also conducted sending messages through different series of the "dispenser," with separate recorders attached to the several series of the "collector" for the purpose of determining that a recorder attached to one series would not print an intelligible message transmitted by a different series. This test was not entirely successful because some of the recorders which should not have recorded did record. No tests were made for distance or interference. Bull did not claim his system immune from interference. During the tests messages were interrupted by transmis-

[13] Letter, dated 20 Aug. 1904, Marconi Wireless Telegraph Co. of America to Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[14] Letter, dated 13 Sept. 1904, Chief of the Bureau of Equipment to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

sions from other stations in the vicinity.[15]

Upon the completion of these tests, the Bureau asked for a tender for two sets of the Bull apparatus, with certain modifications to permit its successful use at sea.[16] In reply, the U.S. Government was offered the exclusive rights to the Bull patents in the United States for the sum of $480,000, or, for $400,000 the right to the manufacture and use of equipment under the Bull patents with the firm reserving the right, and the exclusive right, to sell the use and manufacture of said patent in any other manner it desired.[17] The Navy did not deem it advisable to accept either of these proffers.[18]

THE TEMPORARY PACIFICATION OF FESSENDEN AND TESTS OF HIS APPARATUS

Despite the criticism of Fessenden made by the Department of Agriculture, the Navy continued negotiations with him. In March 1904, he agreed, with reservations, to accept the conditions imposed by the Navy. In these reservations he brought out that his company had offered, for the testing of his equipment, to place at the disposal of the Navy Department stations operating a distance of 80 miles overland, employing antenna 135 feet high, and using between one-fifteenth and one-quarter horsepower of energy. He objected to the expenses involved in the transfer of the company's apparatus to the New York and Navesink stations, which, with the work essential to putting them in proper operating condition, would amount to about $1,000. Considering the ranges he had obtained during the previous 6 months, he felt that such an expenditure was an act of injustice to his company. In view of the fact that, when the De Forest, Slaby-Arco, Braun, and other equipment were tested, the Department purchased sets of apparatus from them, he felt that the Department was discriminating against his firm by requesting it to make the experiments at its own expense. He requested that the Bureau reconsider the matter or permit the tests to be made between the company's New York and Philadelphia stations. The Bureau replied that, while it was willing to test his apparatus under its conditions, it was not willing to do so under protest, and that, furthermore, the Bureau had outlined the test conditions which were the same for all contestants, no others having been agreed to by the Bureau.[19]

There can be little wonder that the Navy had its difficulties in dealing with the amazing and vacillating Fessenden. On 23 May 1904, he proffered two stations at $1 each, capable of communicating 120 miles over water, with the statement:

> Our standard price for two stations such as referred to is $12,000, or $6,000 per station, but that our company has decided under the circumstances to tender for a nominal sum.[20]

Ever the optimist, a few weeks later Fessenden assured Adm. Henry N. Manney,[21] the new Chief of the Bureau of Equipment, that not only could his equipment maintain practically continuous communication between the Nantucket Shoals Lightship

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[15] Report of Wireless Telegraph Board, n.d., files, Bureau of Equipment, National Archives, Washington, D.C.

[16] Letter, dated 29 June 1904, Chief of the Bureau of Equipment to Mr. O. L. Nichols, Coudersport, Pa., files, Bureau of Equipment, National Archives, Washington, D.C.

[17] Letter, dated 23 Sept. 1904, Mr. O. L. Nichols, Coudersport, Pa. to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[18] Letter, dated 16 Jan. 1905, Chief of the Bureau of Equipment to Mr. Anders Bull, Christiania, Norway, files, Bureau of Equipment, National Archives, Washington, D.C.

[19] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., files, National Electric Signaling Co.

[20] Op. cit.

[21] Manney was born in Indiana, appointed a midshipman from Minnesota, and graduated from the Naval Academy in 1866. He became Chief of the Bureau of Equipment in 1904 and held this post until he retired early in 1906. He died at San Diego, Calif., in 1915.

and the Naval Radio Station, Montauk Point, the Torpedo Station, Newport, R.I., and Highland Light, Cape Cod, Mass., but, additionally, his recording and calling instruments would operate over 10 percent longer distances with the same reliability and under the same conditions as recording and calling devices used in any other equipment.[22]

Following additional correspondence and a number of misunderstandings concerning the rules and regulations under which the tests were to be conducted, the National Electric Signaling Co. began to install its own apparatus [23] at the two test stations on 15 August.

The test program included transmitting and receiving for accuracy and speed, the elimination of interference, a determination if messages could be received and sent between two stations, one equipped with the Slaby-Arco and the other with the Fessenden apparatus.

Late in August, the Wireless Telegraph Board assembled for the interference tests, with Rodgers and Edgar at the Brooklyn Navy Yard, Peters and Fiske at the Highlands, and Jayne aboard the U.S.S. *Topeka*. In one test a press dispatch of 861 words was received at the station at Brooklyn at the rate of 20 words per minute, with a loss of 2 words of the headline and 2 mistakes in the text. During the period of this transmission, with the exception of intervals of a few minutes, the *Topeka* was attempting interference by transmitting continuously, while anchored off Tomkinsville, Long Island, distant about 5½ miles from the navy yard.

The America De Forest Wireless Telegraph Co. had constructed a station adjacent to the lighthouse reservation at Navesink. This was only 168 yards distant from the Navy's station. The Fessenden engineers were given 1 week to show that his "interference preventer" would permit reception during the transmissions of the nearby De Forest station. The end of the week found the undesired signals coming through as strong as on the first day and completely blocking out those transmitted by the Fessenden equipment at the Brooklyn station. It was stated at the time that they weren't really signals but more like power to run a lighting circuit. By letter and by telegraph Fessenden insisted that the difficulty was not due to his set, in which he had so much faith that he could not believe anything could interfere. He came to the station to show his engineers, Messrs. Charles Pannill and Arthur Isbell, how it should be done. After adjusting the receiver to signals from a distant station and balancing it out perfectly, he handed the headphones to Captain Rodgers in high expectation of success. Just as he did so the transmitting key at the De Forest station was closed. Pandemonium broke loose. A huge flash appeared where the fine wire of the electrolytic detector entered the platinum cup holding the dilute acid. The acid sputtered all over the room. The spark streamed between wire and cup like a miniature arc lamp. Against such "power interference" the preventer was far from a success. Taking his disappointment in good grace, Fessenden not only made apologies to his men, but, in order to alleviate the whole situation, ordered his assistant to remove the top from the black box, the contents of which he had maintained secret. Having disclosed them, he proceeded to exhibit and explain the highly intricate circuit to the Board,

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[22] Letter, dated 8 June 1904, R. A. Fessenden to the Bureau of Equipment, "Radioana," files, National Electric Signaling Co.; "Tests of the Fessenden System of Wireless," n.d., files, Bureau of Equipment, National Archives, Washington, D.C.

[23] In this apparatus, the transmitter consisted of a rotary converter, providing an alternating current of 70 volts; an oil transformer giving a current of either 12,500 or 25,000 volts; a fixed spark gap with a conducting disk halfway between the discharging knobs with muffier; a condenser utilizing some dielectric other than glass; and an inductance coil. The receiver consisted of a tuning coil, electrolytic detector, telephone, and usual batteries, resistances, and condensers. The aerial was a cage 60 feet long with six no. 16 copper wires, the six taken together forming a rope or "rattail" 160 long leading from the cage to the receiver (Tests of the Fessenden System of Wireless), n.d. files, Bureau of Equipment, National Archives, Washington, D.C.

much to the disgust of Pannill and Isbell, who had so often lugged the heavy box up and down the steep hill to their hotel.[24]

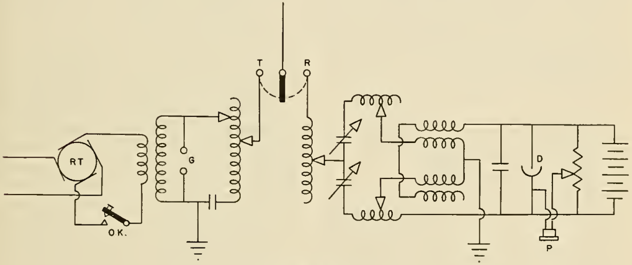
Following these tests, radio equipment was needed for fitting the U.S.S. *Alabama, Illinois,* and *Dolphin.* Three sets of equipment were purchased from the National Electric Signaling Co. to meet this requirement. These were guaranteed to cover distances up to 250 miles.

During the trials of the *Alabama* installation, conducted during January 1905, considerable difficulty was experienced. The maximum distance that signals were received was 70 miles. The transmitter and receiver were both reported inefficient, and considerable corona effect was noted during transmissions. The equipment was not sufficiently rugged for shipboard use, especially in tropical waters where the temperature in the operating room went so high that it caused the Leyden jar condensers to break down.[25]

[24] Helen M. Fessenden, "Fessenden—Builder of Tomorrows" (Coward-McCann, Inc., New York, 1940.), p. 123.

[25] Letter, dated 28 Jan. 1905, Lt. Comdr. W. R. Shoemaker, USN, to Commanding Officer, U.S.S. *Alabama,* files, Bureau of Equipment, National Archives, Washington, D.C.

Schematic Diagram of Fessenden Radio Equipment
Purchased By The United States Navy, 1905



G – SPARK GAP
OK – OPERATOR'S KEY
RT – ROTARY TRANSFORMER
T/R – TRANSMIT-RECEIVE SWITCH
D – DETECTOR
P – HEAD SET

Reconstructed from Information Contained in Robison's Manual of Radio Telegraphy, 1911 and Other Official Navy Records

The receiver in this equipment was of the Interference Prevention type. The currents induced in the antenna have two possible paths to ground one of which is tuned to the receiving frequency, other frequencies supposedly would divide themselves equally in the paths and cancel themselves in the untuned detector circuit

FIGURE 8–1.

The Commanding Officer of the *Alabama,* in reporting to the Commander in Chief, North Atlantic Fleet, included the following statement regarding the Fessenden distance trials:

> In my opinion, it will be impossible to get any more satisfactory results until the installation is put in better shape.[26]

Finally, Manney informed the National Electric Signaling Co. that he had directed the Commander in Chief, North Atlantic Fleet, to permit their representatives to install the firm's latest type condensers on the *Alabama* and the *Illinois.* If the guarantee, to successfully exchange messages up to 250 nautical miles between these two ships, was not fulfilled before the end of the present fiscal year, the removal of the apparatus would be requested.[27] The equipment was improved and retained by the Navy but was never entirely satisfactory and no further purchases were made from that company for several years.

FAILURE OF SOME AMERICAN COMPANIES TO SUBMIT APPARATUS FOR TESTS

De Forest's equipment was never submitted to the Board for test, probably because at this time he was being kept busy installing new and useless stations, and exploiting his equipment at the St. Louis Exposition. The International Co. was absorbed by the De Forest interests and their equipment was never submitted.

The Telefunken Co. must have submitted equipments for the tests, but no positive record of this has been located. Mr. George H. Clark states the Board's final recommendation was favorable to this company,[28] but the only substantiation of this claim was that four sets of their equipment was purchased at about this time. There are no records to indicate that the equipments of James F. King or George S. Piggott were submitted for test. No equipment from either of the individuals was ever purchased by the Navy.

INEFFECTIVENESS OF THE WIRELESS TELEGRAPH BOARD

The testing, which continued through 1904 and a portion of 1905, culminated with a a final report, which, according to a later account of Mr. George H. Clark, stated that Telefunken equipment was the most desirable from the point of view of the Board.[29] While such may have been the expressed opinion at the time, following purchases of Slaby-Arco equipments, in 1903, most of the Navy's radio devices were purchased from American manufacturers. Subsequent events indicate that the Wireless Telegraph Board was dissolved sometime early in 1905. Lt. Comdr. S. S. Robison, USN,[30] relieved Jayne as Head of the Radio Division, Bureau of Equipment, late in 1904. Beginning early in 1905 he personally supervised the tests of equipment of various manufacturers. It is possible that the "Board system" was found to be too unwieldy to satisfy the requirements of a rapidly expanding system. Even during the period of its existence, actions were taken which indicate that its work was not looked upon with too high favor, and it cannot be said that it accomplished anything of note.

[26] Letter, dated 29 Jan. 1905, Commanding Officer, U.S.S. *Alabama,* to Commander in Chief, North Atlantic Fleet, files, Bureau of Equipment, National Archives, Washington, D.C.

[27] Letter, dated 1 April 1905, Chief of the Bureau of Equipment to National Electric Signaling Co., "Radioana," op. cit., files, National Electric Signaling Co.

[28] "Radioana," op. cit. (Clark, "Radio in War and Peace", unpublished manuscript, n.d.), p. 36.

[29] Ibid.

[30] S. S. Robison was born in and appointed a naval cadet from Pennsylvania. He graduated from the Naval Academy in 1888. Subsequently, he was designated a naval constructor. He headed the Radio Division from late 1904 through 1906. He was Chief of the Bureau of Engineering during the years 1925-'28 and was Superintendent of the U.S. Naval Academy from 1928 to 1931. He retired in 1931 and died at Glendale, Calif., on 20 Nov. 1952.

PROBLEMS CONNECTED WITH THE PURCHASE OF EQUIPMENT FOR THE CARIBBEAN RADIO CIRCUITS

One of the most difficult problems confronting the Radio Division, Bureau of Equipment, was providing radio communication service with the newly acquired Panama Canal Zone. This necessitated high-powered stations at Key West, Fla.; San Juan, P.R.; U.S. Naval Station, Guantanamo Bay, Cuba; and in the Canal Zone, Panama. To provide these stations the Bureau of Equipment requested estimates and detailed specifications from the only two American firms which appeared to have the capabilities of providing this equipment, the National Electric Signaling Co. and the American De Forest Wireless Telegraph Co. The successful bidder for the four radio stations would be required to guarantee the maintaining of successful communications between Key West, or some point on the mainland near Cape Florida, and Guantanamo Bay; between Guantanamo Bay and San Juan or some point in the Puerto Rico, and, between Guantanamo Bay and one of the highest points in the Panama Canal Zone. The Navy's letter additionally stipulated:

> Communication to be established between any one of these stations and naval vessels equipped with wireless telegraph apparatus within the radius of communication from the ship, and messages to be received by ships at sea between any two of the stations which communicate with each other.[31]

The National Electric Signaling Co. tendered a bid of $315,000 for the installation and adjustment of their equipment in the four stations and for licensing it for use by the Navy. This did not include power supply, radio masts, nor buildings. In the same letter the company outlined its guarantees and claims, with typical Fessenden extravagance. The following is a paragraph of this letter stating their claims:

> We claim our system is the most reliable, does not require the constant and delicate adjustment which other systems do—Is much less subject to interference from atmospheric disturbances and from other stations — Is specially constructed with reference to convenience of operation and low cost maintenance—That messages can be sent and received much more rapidly than with any coherer system—It is especially constructed for use in moist and tropical climates—It is much more sensitive and requires less power to operate than other systems—Its operation is easily learned and messages can be sent at the rate of 30 to 40 words per minutes—It will, with the same power, transmit messages from two or three times further than any other system—No other apparatus which does not infringe our patents can successfully operate at longer distances than twenty-five (25) miles.—It will transmit code messages correctly under atmospheric or interference conditions when a choherer system could not operate at all. Ships operating this system can read messages from Marconi or Slaby-Arco systems at from two to three times the distances that ships equipped with Marconi or Slaby-Arco systems can communicate with each other—Ships equipped with the Fessenden system can, when desired, communicate with each other to the full working distances without Marconi or Slaby-Arco equipped vessels in the near neighborhood being able to detect that communication was taking place.[32]

The firm guaranteed communication between the four stations; that Fessenden equipped vessels, having 130-foot masts, would be able to receive communications from either one or the other of two communicating stations while between them; that vessels equipped with apparatus equally as sensitive and reliable as Fessenden apparatus could receive communications from either one or the other of the two communicating stations while between them; and that vessels equipped with Marconi or Slaby-Arco equipments would be able to communicate with the four stations over greater distances than they could with stations of the Marconi or Slaby-Arco type. They guaranteed to defend, at their own expense, any and all suits brought against the Government for infringement or alleged

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[31] Letters, dated 22 and 23 June 1904, National Electric Signaling Co. to Chief of the Bureau of Equipment; Letters and contracts, dated 16, 22, and 29 June 1904, American De Forest Wireless Telegraph Co. and Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[32] Letter, dated 20 June 1904, National Electric Signaling Co. to Bureau of Equipment. "Radioana," files, National Electric Signaling Co.

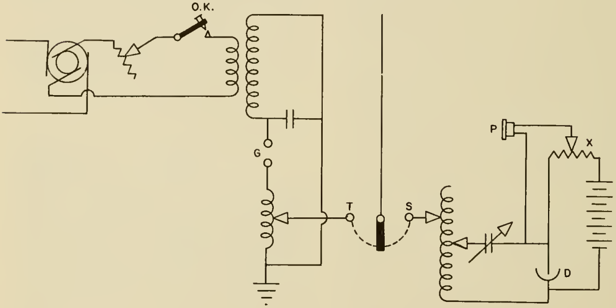
infringement of patents due to the use of apparatus sold or installed by them.[33]

The license clause submitted as part of this tender differed from that of the Marconi companies. The latter permitted the use of its equipment for commercial traffic but required the tolls be paid them. The National Electric Signaling Co.'s clause prohibited the use of the equipment for the handling of commercial traffic. The contract for the three Fessenden equipments, purchased at about this time, for installation in naval vessels did not include such a proviso. This license clause was not acceptable to the Navy since there was no intention of purchasing equipment with restriction as to its usage. The company was adamant and their refusal to abandon it eliminated consideration of their bid.[34]

[33] Ibid.

[34] Letter, dated 23 June 1904, H. W. Young, National Electric Signaling Co., to Hay Walker, Jr., President, National Electric Signaling Co., "Radioana," op. cit., files, National Electric Signaling Co.

Schematic Diagram of DeForest Radio Equipment Purchased for Installation in United States Naval Radio Shore Stations in The Caribbean Area



OK – OPERATOR'S KEY
G – SPARK GAP
T/S – TRANSMIT-RECEIVE SWITCH
D – DETECTOR
P – HEAD SET
X – POTENTIOMETER

Reconstructed from Information Contained in Robison's Manual of Radio Telegraphy, 1911 and an Article Entitled Wireless Telegraph Service in St. Louis by Cloyd Marshall as Contained in the September 3, 1904 Issue of Electrical World and Engineer Volume XLIV, No. 10

In these installations DeForest first used the Pancake Tuner which consisted of a flat spiral of insulated wire on glass. One spot in each turn had the insulation removed to form an arc of the uninsulated points. An arm was pivoted at the center of the circle of which this arc was a portion so that it could be made to form contact with an uninsulated point

Shoemaker Radio Equipment purchased by the United States Navy in 1906 was similar to this equipment

Figure 8–2.

Following the elimination of the National Electric Signaling Co., by its own action, the American De Forest Radio Co. was awarded the largest single contract for radio equipment yet entered into by the Navy. This called for the provision and installation of three 35-kw. transmitters, together with receiving apparatus with telephone attachment and call bell, antenna, and ground systems and all accessories, one each at Key West, Fla., Guantanamo Bay, Cuba, San Juan, P.R., and the Canal Zone at a total cost of $58,666. A fifth unit, identical with the others except that the transmitter was only 10 kw., was added for installation at Pensacola, Fla., at a cost of $7000. The Navy was required to provide power, radio masts, and buildings and transport the equipment to locations outside the continental limits.[35]

The provisions of the contract required the contractor to furnish satisfactory bond in the amount of $16,416 as a guarantee for the faithful performance of the contract; that the contractor, in addition to supplying all labor necessary to satisfactorily make and install the apparatus, would also provide the services of skilled operators to care for and use the apparatus for such time as would be necessary to satisfy the Bureau of Equipment that the conditions of the contract were fulfilled; that the contractor would protect the Government against all claims for infringement of patents which might arise from the use of apparatus to be supplied under the contract; that the contractor guarantee to complete the installations within 6 months from date of contract, and to have same in satisfactory operation within that time, provided the Bureau of Equipment erected the necessary masts, buildings, and machinery within 5 months from date of contract; and provided also that any delay beyond the 5 months in erecting above masts and supplying power would be added to time allowed the contractor; provided, further, it could be shown that such delay had caused the contractor any delay in the execution of his contract. No payment was to be made until it was demonstrated to the Bureau of Equipment that all material and labor required under the contract had been supplied, and the radio service provided by its terms had been satisfactorily established.[36]

The time clause of the above-noted provision was invoked by the company, on 16 December 1904, when White, its president, notified the Bureau of Equipment that it would be inadvisable to ship the apparatus to distant places like Panama, Puerto Rico, and Guantanamo Bay until storage suitable for protecting it against the elements was provided and facilities for installing it were afforded his company.[37]

ADDITIONAL FESSENDEN COMPLAINTS

On the date of the signing of the contract with the American De Forest Wireless Telegraph Co. the Bureau advised the National Electric Signaling Co. of its action.[38] Learning of this the same day, Mr. H. W. Young, attorney for the National Electric Signaling Co., in a letter to Mr. Hay Walker, Jr., who, with Mr. Thomas H. Given, provided the financial support of the company, noted that "we will be unable to do any business with the Navy unless we come to their terms, particularly in that relating to licenses which they will utterly refuse to consider. If we do not furnish apparatus without any license restriction, I feel certain that we

[35] Contract No. Special 61, dated 29 June 1904, the American De Forest Wireless Telegraph Co. of Portland, Maine, and the US Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[36] Ibid.

[37] Letter, dated 16 Dec. 1904, American De Forest Wireless Telegraph Co. to the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[38] Letter, dated 29 June 1904, Chief of the Bureau of Equipment to National Electric Signaling Co., "Radioana," op. cit., National Electric Signaling Co.

might as well refrain from bidding." [39] This letter brought out various points concerning the Navy's position. Although the price the National Electric Signaling Co. quoted was nominal in comparison with the cost of cable, that was a matter the Navy Department would not consider, since they took the stand that it was simply a case of meeting competition and not a case of comparing the cost of radio with those of cables. In making this cost comparison the company had furnished the Navy with a memorandum, one paragraph of which reads:

Such a cable would, however, not by any means be the equivalent of the wireless stations referred to as by the contract any one wireless station is to be capable of communicating with any other, while if the cable were cut at any one point, it would sever all communication. An exact equivalent, more especially for military purpose would be cables connecting every one of the four points direct to every other one, which would call for approximately 4,400 miles of cable the cost of laying which would be in the neighborhood of $3,000.00. In addition, communication between U.S. war vessels and shore would not of course be accomplished if cables were used.[40]

Young continued, stating that the company would have to accede to the Navy's demands or relinquish any hopes of obtaining contracts. He closed his comment with this statement:

I believe the entire Navy business can be summed up in saying that if we wish to do business with them, the contracts must be drawn without license restrictions, guarantees made exceedingly broad, forfeits put up and the price made competitive with other people now in the market.

Commenting upon the De Forest Co. he considered they could afford to make the above concessions since their revenues would be derived from selling stock and not from the profits on installations.[41]

Events were soon to prove the correctness of Young's last statement. With the contract signed, sealed, and delivered Abraham White, alive to its stock selling potential, had this factless statement inserted in the press:

With the greatest care the Government experts conducted most rigid tests and reported that the De Forest system already executing Government contracts on a smaller scale, was the one which offered the best service although its terms were higher than those of other companies. During the tests, which extended over a period of several months, seven wireless stations were in simultaneous operation in the same magnetic field and yet long messages were successfully transmitted and received by the De Forest system. This achievement, regarded by the government expert as the greatest in the history of the science, was possible only by the utilization of "syntonic aerography" in which the De Forest attuning apparatus is employed. It is a source of pardonable patriotic pride that this remarkable instrument is the product of the inventive genius of Lee De Forest, Ph.D. (Yale), a young American, who has been responsible for so much of the wonderful progress made in wireless work within the past 10 years. In the war maneuvers of 1902, and again in 1903, the Government experts reported that this was the only system that operated under all the difficulties attendant on the work and the service during the recent tests conclusively demonstrated that ability of utilizing it to transmit messages without interference because of the location of similar stations in the same magnetic zone and with the possibility of their interception by other systems totally eliminated. As a result the Government has entered into a reciprocal contract with the company which makes them, in a sense, allies.

By its terms—and this is the most important consideration to the business world—commercial messages are exchangeable between all stations and ships equipped with the De Forest instruments, whether maintained by the government or by the company. For this purpose all the war vessels of the American Navy will be equipped with the De Forest attuned apparatus, and all messages will be transmitted between war vessels and passenger steamers, and between land stations irrespective of whether they are under the control of the Government or the company. The chain of communication thus established is practically one system operated in part by the Government and partly by the De Forest Co. It is understood that having thus adopted the De Forest system and entered into such a combination with the company controlling it, the Government is guaranteed against the employment of the system in any manner which might prove detrimental to its interests and it is reported that its exclusive use for war vessels has been guaranteed to the U.S. Navy.[42]

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[39] Letter, dated 29 June 1904, H. W. Young to Hay Walker, Jr., "Radioana," op. cit., files, National Electric Signaling Co.

[40] Ibid.

[41] Ibid.

[42] New York Herald, 11 July 1904.

Upon becoming aware of this published item, the National Electric Signaling Co. immediately requested clarification of the Bureau concerning the statements appearing in the press. It requested verification of the statements to the effect that "all the war vessels of the American Navy will be equipped with the De Forest apparatus"; that the Government had "adopted the De Forest system and entered into a combination with the company controlling it"; and, that the Navy contracts "for the Gulf of Mexico," as it phrased it, had been awarded as the result of "most rigid tests conducted by Government experts, extending over several months, who reported that the De Forest system was the one which offered the best service, though its terms were higher than those of other companies." [43] Fessenden also contacted Jayne, and provided him with a copy of the article sent out to the press by the De Forest Co. He regarded this as a distortion of facts and asked that the Department issue a simple statement stating the true facts without prejudice to either party.[44]

In reply to these questions and the request, the Bureau stated that it could not be concerned with the various newspaper articles which appeared from time to time on the subject and that it did not care to express an opinion regarding their accuracy. However, the statements, to which the National Electric Signaling Co. referred, were not true, and the purchase of the instruments was not the result of any tests conducted by the Bureau.[45]

Later, the Bureau of Equipment did protest the inclusion of the statement, "Used and indorsed by the U.S. Government" on the letterheads of the American De Forest Wireless Telegraph Co. This afforded White an opportunity to state the justification for such use by reporting that, in 1902, during the war maneuvers, its system was employed by the Signal Corps, U.S. Army, and in an official report of that year the Chief Signal Officer had highly endorsed and approved its use by the Army. In 1903 the system was again used successfully by the Signal Corps, and in 1904 the Navy gave the De Forest firm the largest radio contract ever granted by the Government. The firm knew that it told the truth when it stated that the Government endorsed its system, and White wished to go on record that he considered it unjust to be requested to refrain from using what he considered a true statement. In justification he analogized that chowchow pickles were used and endorsed by Her Majesty, the late Queen Victoria of England, and the labels on the bottles so stated, yet he did not doubt that the Queen used other pickles as well. Since the firm had never stated, so far as he was able to determine, that the Government used the De Forst system exclusively, the Bureau had no cause to read that meaning into the statement.[46] Forced to agreed with the legality of White's position, the Bureau withdrew its objection and thereby provided unwilling assistance to his fraudulent schemes. In passing, it is only fair to add that, from that time, no further purchases were made from the American De Forest Co., nor from its successor, the United Wireless Co.[47]

The specified date of completion of the stations for the Caribbean circuits was far more optimistic than any which could have reasonably been expected under existing circumstances. There were delays for which

[43] Letter, dated 12 July 1904, National Electric Signaling Co. to Chief of Bureau of Equipment, "Radioana," op. cit., files, Natinoal Electric Signaling Co.

[44] Letter, dated 12 July 1904, R. A. Fessenden to Lt. Comdr. J. L. Jayne USN, "Radioana," op. cit., files, National Electric Signaling Co.

[45] Op. cit., Clark, letter of 14 July 1904 from Chief of Bureau of Equipment to National Electric Signaling Co., files, National Electric Signaling Co.

[46] Letter, dated 8 May 1905, Abraham White, President, American De Forest Wireless Telegraph Co., to Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives Washington, D.C.

[47] Letter, dated 12 May 1905, from Chief of Bureau of Equipment to Abraham White, President, American De Forest Wireless Telegraph Co., files, Bureau of Equipment, National Archives, Washington, D.C.

the Navy was responsible, others caused by "acts of God," some by lack of understanding of tropical terrain and atmospheric conditions. White, with his experience in avoiding contractual responsibilities, had little difficulty in convincing the Navy Department that his company should not be held responsible or penalized for failure to meet the time requirements.

All the stations were completed by late 1905 except the one at Guantanamo Bay, Cuba. This was not completed until early 1906. Except during periods of intense atmospheric disturbances the stations were able to communicate with each other as well as could be expected considering the state of the art at that time.

The experiences during the construction of the station at Guantanamo Bay are of interest since they described the difficulties in constructing radio stations at that period. The Navy's base on this bay was at that time a dense jungle interspersed with low sand flats. The exact location for radio installation had been selected in Washington, well to the northern end of the bay, across a narrow inlet from the village of Bogueron. This location was chosen to provide it with maximum protection from seaward bombardment. It was on a desolate, almost inaccessible coral promontory entirely lacking of good ground facilities. At this "hellhole of wireless," and "paradise for mosquitoes, fleas, horned toads, snakes, scorpians, centipeds, tarantulas, wildcats, and all other kinds of tropical pests, flying and crawling," as De Forest described it, he and his assistant, Mr. Frank Butler, learned many lessons in the construction of radio stations in tropical areas. The consensus of opinion of the construction force was contained in a printed sign above the door of the operating building which read, "Abandon hope, all ye who enter here, for verily this is hell." [48] A monitor, the U.S.S. *Amphridite,* was anchored in the harbor and served as headquarters for the entire reservation. Its commanding officer was also in charge of the station. She had brought the officers and men for the construction of the new base, including the radio towers and buildings. Three electrician's mates, John Watts, Roscoe Kent, and V. Ford Creaves, were assigned to assist Butler in his work.

The three masts for the station, each 208 feet high, had been towed from the States and erected at the corners of a 300-foot triangle, with the building housing the equipment centered in the area. From a stout cable, connecting the tops, 45 individually insulated, stranded phosphor bronze wires were suspended from each of the 3 masts. The lower ends of these 135 wires were soldered together into a large "rattail" at the center, anchored by a wooden frame, and led through a large porcelain insulator into the condenser room. In writing of it, Butler said:

> The huge cage resembled a giant gold fish globe 200 feet high, and months afterward, when the station was in operation the nest of wires would emit a bluish discharge at night which was beautiful beyond description and always proved of unending awe to the natives who would stand off from afar and gaze in open-mouth wonder.[49]

Week after week new and unforseen troubles presented themselves, and it seemed they were waging a hopeless battle against nature. The following notes from Butler's diary give a vivid picture of the struggle:

> June 5th Bi 50 H.P. motor generator blew up, damaging armature.
>
> June 12th. Commenced repairing damaged trays in condensers.
>
> June 14th. Lined condenser trays with portland cement.
>
> July 13th. Terrific storm 2:30 a.m. Lightning struck station bursting an entire room full of condensers—just finished after two weeks of hard work—throwing oil and plate glass all over the room and into the walls.
>
> August 21st. Small cyclone struck us.
>
> August 31st. Lightning struck the station at 4:15 p.m. blowing up one set of condensers.

[48] Lee De Forest, "Father of Radio" (Willcox & Follet Co., Chicago, 1950), pp. 178-181.

[49] Frank E. Butler, "How Wireless Came to Cuba", Radio Broadcast, November-April. 1924-25, p. 916.

September 5th. No fresh water. Had to drink salt water all day.

September 24th. Another entire span of 15,000 feet antenna wire blew down.

September 27th. Touched off station again and blower motor blew up.

October 8th. Herd of horses from workmen's camp broke corral in night and demolished the guy wires on the entire aerial spans twisting wires badly.

October 15th. Earthquake 4:43 p.m. while eating supper.[50]

But despite the endless delays, setbacks, and discouragements, the struggle continued until, finally, the installation was completed and ready for tests. When these were commenced it was discovered that with the two-coil slider, the principal tuning device, it was impossible to eliminate the constant and terrific static. De Forest realized that it was necessary to improve the tuner or fail to meet the contract specifications. The resulting adverse publicity would certainly cause the loss of sales of stock. De Forest therefore hastened to New York to attack this problem. Faced with necessity, he invented the pancake tuner which became one of the chief elements of the success of the tropical installations.[51]

By March 1906, all the troubles had been overcome and communications were established and maintained with the other stations to the satisfaction of the Navy. Butler wrote, "When the end finally came, when my work was finished, I was more than overjoyed to get away from that place of trials, but I was sorrowful to leave my three faithful naval companions, Watts, Kent and Greaves." [52]

An interesting sidelight in connection with the construction of these stations quickly brought it to the attention of the world by the publicity-minded De Forest Co. After the completion of the Key West installation, that company built a station at Manhattan Beach, Coney Island, which was to be "the daddy of them all." [53] This giant, America's first 50-kw. radio station, with its two 210-foot wooden towers, was located in a salt-water swamp which was considered to be a perfect location for oversea operations. On the night of 19 December 1905, this station was heard by the Navy's newly completed Canal Zone station. This was considered a remarkable feat and provided sufficient encouragement to cause Manney to permit an official statement to be issued which read, in part:

The distance between Colon and Manhattan Beach, the extreme range of the message, is 2,150 miles. So extraordinary was this feat that the Bureau hesitated about making it public, and has only done so after receiving corroborative evidence from several points. This not only beats any previous record made by the Bureau but it beats the record of the first transatlantic cable, which reached only 1,860 miles from the west coast of Ireland to Newfoundland.[54]

FESSENDEN CONTINUES HIS COMPLAINTS AGAINST THE NAVY

At about the time the stations for the Caribbean circuits were completed, the Navy placed an order with the American De Forest Co. for electrolytic detectors. The purchase of these was protested by the Fessenden interests, who claimed De Forest was infringing their patent. With Fessenden's anger at the boiling point, the letter carrying the protest contained the following paragraph:

Before taking the action to which I have been advised I have decided to endeavor to bring the matter before His Excellency the President of the United States, in the hope that his strong sense of justice will lead to a change in the present departmental practice in regard to inventions.

Fessenden continued the letter, asking the Secretary if he preferred to arrange that his firm have the opportunity of presenting its case before the President, with a view to ascertaining the possibility for some ruling or legislation by which the departments of the U.S. Government should recognize the decision of the Patent Office and of the

[50] Butler, op. cit., p. 919.

[51] Ibid., p. 920.

[52] Ibid.

[53] De Forest, op. cit., pp. 193-194.

[54] Ibid.

U.S. courts in regard to property rights in inventions, and in regard to compensation to be made, or would he prefer for him to make the arrangements through the Senator of his State.[55]

The question as to the validity of the protest was referred to the Secretary of the Navy, who directed the purchasing authority as follows:

Respectfully returned to the Bureau of Supplies and Accounts, with instructions to disregard, in awarding this contract, the protest of the National Electric Signaling Co. The Department holds that the bids received indicate so strongly the probability that this company is asking an extortionate price of the Government that it feels it is relieved of any moral obligation which might otherwise exist in the premises—without deciding that any such obligation would exist—to lend its aid to the vindication of the legal rights of the said company under the patents it claims.[56]

Failing in his attempt to intimidate the Secretary of the Navy, Fessenden next resorted to the failure of the American De Forest Wireless Telegraph Co. to meet the dates specified in their contract as a means of continuing his unrelentless belaborings. In another letter to the Secretary of the Navy his company stated:

We are reliably informed that though two years have elapsed since the De Forest Co. was given the contract these stations are not yet complying with the terms of the contract, i.e., are not communicating regularly with each other, not being able to communicate, in the case of a majority of the stations, at all during daylight, and not regularly during the nighttime.

Our company pointed out at the time the contract was let that the contracting parties would not be able to maintain regular communication with the stations proposed, and at the price quoted, and it would now appear that our prediction has been verified and that the Navy Department has paid a large sum of money for stations which are inoperative during the greater part of the time.[57]

[55] Letter, dated 5 Apr. 1906, R. A. Fessenden to Secretary of the Navy, "Radioana," National Electric Signaling Co.

[56] Letter, dated 19 Apr. 1906, Secretary of the Navy to R. A. Fessenden, "Radioana," National Electric Signaling Co.

[57] Letter, dated 6 June 1906, National Electric Signaling Co. to Secretary of the Navy, "Radioana," National Electric Signaling Co.

This letter informed the Secretary that the Fessenden firm had erected two stations, of the type which it had proposed to furnish in the West Indies, which had been able to communicate at night and for some hours of daylight over a distance of 3,000 miles, and there was no question that these would be able to work at all times of the day and year between the Navy's West Indian sites, since none were more than 1,000 miles apart. It advised that had the Navy Department accepted the National Electric Signaling Co.'s bid it would have obtained stations capable of operating reliably and they would have been in operation years ago; therefore, they "would respectfully protest against the matter being left as it now stands." Since the De Forest Co. failed to fulfill its contract, the Navy Department "has been deceived into paying out a large sum of money for inoperative apparatus." The firm did not hesitate to offer its advice, stating:

We would respectfully suggest that the Navy Department bring suit against the De Forest Co. for the return of the money paid out, on the ground that the stations are not maintaining regular communication as called for by the contract, and that the time for the completion of these stations is now more than a year overdue, and that the contract with the De Forest Co. be canceled and the tender of the National Electric Signaling Co. for these stations be accepted.

If their advice proved acceptable they guaranteed to erect stations, capable of regular communication which would fulfill all the terms of the contract, in less than half the time taken by the De Forest Co.[58]

Intent upon keeping their complaints in the forefront, they followed this 5 days later with another letter which stated:

We would respectfully call attention to the great waste of public money on the part of the Department though the purchase of cheap and inferior wireless apparatus, purchased from inexperienced makers who have but little knowledge of the requirements of practical wireless telegraphy and who

[58] Letter, dated 11 June, National Electric Signaling Co. to Secretary of the Navy, "Radioana," National Electric Signaling Co.

make a living by pirating the inventions of other companies.[59]

This letter continued with an offer to supply the Navy with apparatus at $12,500 per set.

The reply to these letters included the following statements of the Bureau of Equipment:

> The National Electric Signaling Co.'s latest bid for wireless telegraph sets suitable for ship's use is $12,500 per set.
>
> At such a price a contract for 25 sets, as referred to in paragraph 4 of the enclosed letter, would involve an expenditure of $300,000, which is a greater sum than the appropriation available for wireless telegraphy will warrant.
>
> The apparatus supplied by this company now in use is giving satisfaction, but not more so than other sets installed.
>
> The company refuses to sell any apparatus supplied by it unless purchased in entire sets. For instance, the interference preventer can be attached to any receiving apparatus using a telephone, but the company refuses to sell unless the other parts of an entire set are purchased at the same time.
>
> The Bureau will request the detail of an officer to inspect and report on all of the apparatus enumerated in the second sentence of paragraph 4 within whenever the company is ready to present it for test.
>
> The Bureau's experience with apparatus furnished by this company is to the effect that it is subject to the same defects in many respects as apparatus furnished by other wireless telegraph companies.
>
> The statements in paragraph 5 are in line with previous statements by this company; viz: that its apparatus covers all possible good points of all wireless telegraph apparatus. This is not sustained in practice.
>
> The Bureau recommends that the company be informed that offers by it for apparatus, whole sets or for separate attachments, such as secrecy senders, interference preventers, antiatmosphere apparatus, and intensity regulators, will be considered if priced separately and prices based to a certain extent on the cost of manufacture.
>
> The Bureau considers the company's present prices altogether too high.[60]

Following this, neither the records of the Navy Department nor those of the National Electric Signaling Co. disclose further correspondence on this or on related matters, except a copy of a letter, dated 3 April 1907, which Fessenden was, by the company records, purported to have sent President Roosevelt. This states that he had been advised to bring action before a U.S. court for the disbarment of a member of the President's Cabinet for the commission of a most unjust and improper act punishable by a term of imprisonment when committed by one not occupying an official position. He considered it only proper that he lay the matter before the President, personally, before taking this action. His Secretary of the Navy, Bonaparte, had permitted the purchase of property from a party whom the U. S. courts had already decided, in no less than four decisions, was not the owner of this property. Moreover, he had allowed this despite several formal protests on the part of the parties whom the court had adjudged to be the owners of the property, although the decisions of the courts had been called to his attention, both by personal interview and by copies of the decisions. Handwritten on the copy of this letter is the notation "No reply received." [61]

TESTS AND PURCHASES OF EQUIPMENT DEVELOPED BY JOHN STONE STONE

The Stone Telegraph & Telephone Co. of Boston, Mass., on 11 March 1905, made application to the Chief of the Bureau of Equipment for permission to install a selective system of radio invented and patented by Mr. John Stone Stone, at four stations, the navy yard, Charlestown, Highland Light

[59] Letter, dated 2 June 1906 (mailed 11 June), to Secretary of the Navy from National Electric Signaling Co., Clark, "Radioana," National Electric Signaling Co.

[60] Letter, dated 21 June 1906, Secretary of the Navy to National Electric Signaling Co., "Radioana" National Electric Signaling Co.

[61] Letter, dated 3 Apr. 1907, unsigned rough copy, partly typewritten and partly in long hand, addressed to the President of the United States, "Radioana," files, National Electric Signaling Co. The author is of the opinion that this letter was never transmitted and this opinion is somewhat substantiated by the letter referenced in footnote 55.

Station, Cape Cod, and Thatcher's Island Station, Mass.; and the navy yard, Kittery, Maine.[62]

These installations were to be at the expense of the company, as was the instruction of the Government operators in its maintenance and use. The use of the apparatus was to be allowed for Government purposes for a period of 3 months from the date of the installation, after which it was to be removed by the applicants, or turned over permanently to the Government on mutually agreed upon terms. The company claimed that each of the four stations could communicate with any of the others at will to the exclusion of the others, but without interference to simultaneous operation. It guaranteed entire freedom from disturbances caused by atmospheric, electrical, or other conditions. Messages would be received at all times with clearness and precision equal to the best wire service, and the speed of transmission would be limited only by the ability of the operators. The apparatus to be furnished would be commercially complete in all respects, of such simplicity as to be readily manipulated by any government operator after instruction, and so constructed as to be free from injury by any error in manipulation.[63]

The firm proposed to make the installations at the first two of the above-mentiond stations forthwith, and at the others as soon as the appartus could be manufactured. Accompanying the offer was a copy of a seven-page report, dated 3 March 1905, on the Stone wireless telegraph system by Mr. Louis Duncan, a consulting engineer, the first paragraph of which describes the nature of the system briefly:

> The system of the Stone Wireless Telegraph Company is a selective system designed to transmit messages by electric waves of a determinate character; and at the receiving end to receive only the messages transmitted by the waves to which the particular station is tuned. To do this, the sending apparatus is so arranged that a simple harmonic electrical wave of any desired period or frequency is used for sending, while the receiving mechanism is rendered selective in its actions by means of resonant circuits made responsive to waves of only one period. If electrical waves of other periods impinge on the conductor at the receiving station, the registering apparatus will not be influenced, provided the period of the waves is outside of the region of selectivity. In other systems of wireless telegraphy, the sending station produces waves that are composed of a number of periods, while the receiving stations are not so arranged as to select signals sent from one station. It is evident that unless the sending station can produce waves of one period only, it will be impossible to so construct the receiving station as to put it in selective connection with any particular sending station. It is also necessary, of course, that the receiving station shall receive within narrow limits waves of one definite period only.[64]

In March the Bureau expressed its willingness to permit the installations at the Boston, Mass., and Portsmouth, N.H., Navy Yard and on the U.S.S. *Lebanon,* then being fitted out at the latter port.[65] This offer was accepted and the installations were made. Tests were conducted between the Boston and Portsmouth stations which were observed by Robison. During the greater part of these tests, the Highland Light Station transmitted on the same frequency with full power but caused no interference. Later, when using the navy yard station to create interference and the Stone Co.'s station in Boston for receiving the Portsmouth station's transmissions, the navy yard signals could not be eliminated unless the transmitter power was reduced so as to give maximum signal strength in the receiver but little greater than the maximum signal strength of Portsmouth's signal.[66]

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[62] Letter, dated 11 March 1905, Stone Telegraph & Telephone Co. to Chief of Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[63] Ibid.

[64] Report, dated 3 Mar. 1905, Louis Duncan, "Stone Wireless Telegraph System," files, Bureau of Equipment, National Archives, Washington, D.C.

[65] Letter, dated 24 Mar. 1905, Chief of the Bureau of Equipment to Stone Telegraph and Telephone Co., files, Bureau of Equipment, National Archives, Washington, D.C.

[66] Letter, dated 13 Dec. 1905, Lt. Comdr. S. S. Robison, USN, to Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

Robison's complete technical report included the fact that the transmitter appeared to disseminate a single frequency rather than the usual two. He recommended that the sets at Boston and Portsmouth be purchased under certain provisions, one of which was that the company guarantee to protect the Government against all claims for infringements of patents on the apparatus supplied. Earlier in November the company had offered the Bureau of Equipment eight of its sets at prices ranging from $3,000 to $3,500 each, and this offer was accepted. Those installed at Boston, Portsmouth, and on the *Lebanon* were among the eight.[67]

[67] Tender of the Stone Telegraph & Telephone Co. to Bureau of Equipment, n.d., files, Bureau of Equipment, National Archives, Washington, D.C.

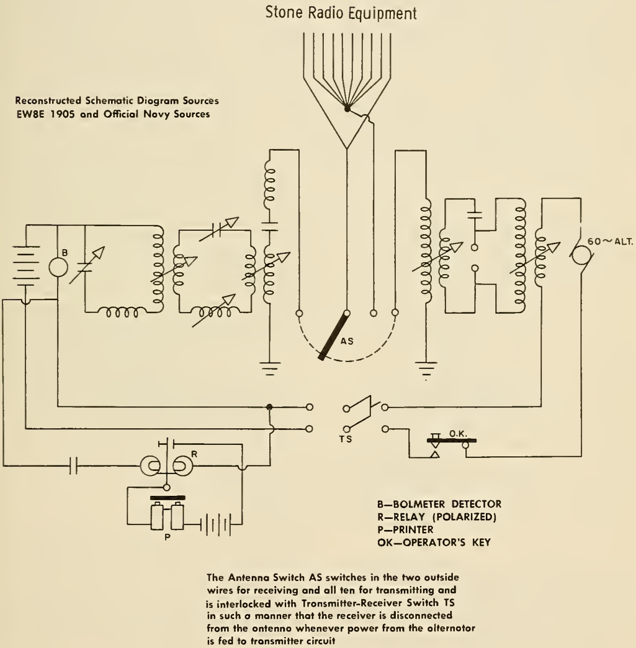


FIGURE 8–3.

PURCHASE OF MASSIE EQUIPMENT

The Scientific American edition of 20 May 1905 carried a Supplement which contained an article by Mr. A. Frederick Collins entitled "The Massie Wireless Telegraph System." At that time this system was in use at the Block Island and Point Judith, R. I., stations of the Providence (R. I.) Journal and at the Wilson Point Station used by the New York, New Haven & Hartford Railway in the control of their steamers plying Long Island Sound. The Block Island Station habitually was able to copy vessels, contacting the Nantucket Shoals Lightship when they were 60 miles from that vessel inbound, or about 150 miles from Block Island.

The article stated that Massie's system combined the advantages of the coherer and microphonic detector by using the former only as a call-bell detector and an improved form of the latter for aural reception.[68]

This article also evinced the interest of Robison and when, later in that year, the Navy required additional radio equipment the Massie Wireless Telegraph Co. was provided with the specifications and requested to submit its bid, along with the International Wireless Telegraph Construction Co., the Telefunken Co., the Marconi Wireless Telegraph Co. of America, and the American De Forest Wireless Telegraph Co. A contract was awarded them for the delivery of 10 complete sets of equipment to be delivered to the New York Navy Yard by 15 January 1906. Two of these were to be supplied with 15-kw., two with 10-kw., three with 5-kw. and three with 3-kw. transmitters. The total amount of the contract was $15,000.[69] A change in the contract increased the number of complete sets to 13 with 5 having 5-kw. and 4 having 3-kw. transmitters.

PROCUREMENT OF SHOEMAKER EQUIPMENT

It has been previously mentioned that Shoemaker became an engineer for the American De Forest Co. when it absorbed the International Co. He remained in their employ a few months and then resigned because of a disagreement with De Forest. With Firth, he established the International Wireless Telegraph Construction Co. and immediately began to build rugged reliable radio equipments. Although his firm was sued for infringement by the De Forest interests he was able to remain in business several years but when Firth, because of a disagreement, left the company and withdrew his financial support, he again fell into the clutches of Abraham White who had gained control of the firm.[70]

At the time the Massie Wireless Telegraph Co. was awarded their contract, Shoemaker was awarded one for 21 complete sets of apparatus. Five of these were supplied with 5-kw., nine with 3-kw., one with 2.5-kw., three with 2-kw., two with 1.7-kw., and one with 1.25-kw. transmitters.[71] This equipment came to be regarded as the best of its time by naval radio operators. Shoemaker was a most capable radio engineer and had he been able to obtain adequate financial support he might have established a continuing business. Eventually, he became associated with the Marconi interests.

OTHER PURCHASES DURING THIS PERIOD

In addition to the above, two additional installations were purchased from the American De Forest Co., four from Telefunken,

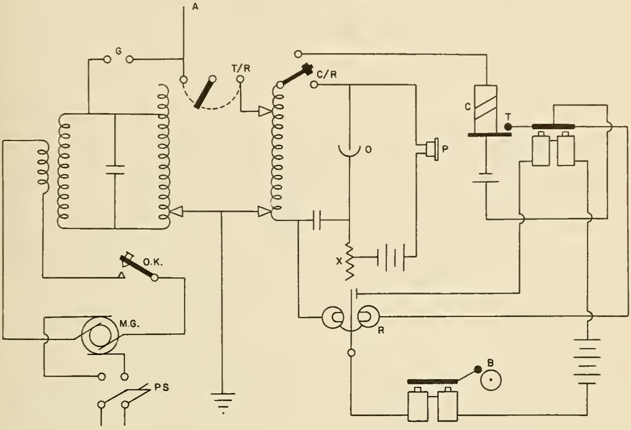
[68] A. F. Collins, "The Massie Wireless Telegraph System," Scientific American, supplement No. 1533, 20 May 1905, pp. 24560-24561.

[69] "Memorandum of Bids for Wireless Signaling Apparatus," opened at Navy Post Office, Washington, D.C., 29 Nov. 1905, at noon., "Radioana," files, National Electric Signaling Co.

[70] Frank Fayant, "The Wireless Telegraph Bubble," Success magazine, June 1907.

[71] Analysis of incomplete equipment records and contracts in the files of the Bureau of Ships, Department of the Navy.

Schematic Diagram of Massie Radio Equipment
Purchased By The United States Navy, 1906



G – SPARK GAP
OK – OPERATOR'S KEY
MG – MOTOR GENERATOR
PS – POWER SWITCH
A – ANTENNA
g – GROUND
T/R – TRANSMIT-RECEIVE SWITCH
B – CALL BELL

C – COHERER
O – DETECTOR
P – HEAD PHONE
R – POLARIZED RELAY
T – DECOHERER
X – POTENTIOMETER
C/R – CALL-RECEIVE SWITCH

Reconstructed from Information Contained in Robison's Manual of Radio Telegraphy, 1910 and an Article Contained in The Electrical World and Engineer, 1905, Volume XLVI, No. 5, pp 178-180, entitled Massie System of Wireless Telegraphy by A. Frederick Collins

FIGURE 8–4.

three from the Massachusetts Wireless Equipment Co., and one from the W. J. Clarke Co.[72]

[72] Ibid.

RADIO EQUIPMENT IN USE IN THE U.S. NAVY IN 1906

Between the time when the second order for Slaby-Arco equipment was placed and the end of 1906 the Navy had purchased the following equipment for installation:

International Telegraph Construction Co. (Shoemaker)

5 5=kw. transmitters:
St. Augustine and Jupiter Inlet, Fla.; U.S.S. *Montana, Idaho* and *North Carolina.*

2 1.7=kw. transmitters:
U.S.S. *Charleston* and *Rhode Island.*

1 2.5=kw. transmitter:
U.S.S. *Pennsylvania.*

1 1.25=kw. transmitter:
U.S.S. *Maryland.*

9 3=kw. transmitters:
South Dakota, Virginia, Connecticut, Washington, Tennessee, New Jersey, Louisiana, St. Louis and *California.*

3 2-kw. Transmitters:
U.S.S. *Ohio* and *Milwaukee;* Puget Sound Navy Yard, Wash.

Massie Telephone and Telegraph Co.

5 5=kw. transmitters:
Beaufort, N. C.; Charleston, S. C.; Table Bluff, Oreg.; Point Loma and Farralones Islands, Calif.

2 15=kw. transmitters:
Washington, D. C. and Tatoosh Island, Wash.

2 10=kw. transmitters:
Cape Blanco, Oreg. and North Head, Wash.

4 3=kw. transmitters:
Point Arguello, Calif.; Puget Sound Navy Yard, Wash. (2); Cape Henlopen, Del.

Stone Telephone and Telegraph Co.

3 5=kw. transmitters:
U.S.S. *Kansas* and *Mississippi:* U. S. Naval Academy, Annapolis Md.

1 3=kw. transmitter:
U.S.S. *Minnesota.*

4 2=kw. transmitters:
U.S.S. *Georgia* and *Lebanon:* Boston, Mass and Portsmouth, N. H.

National Electric Signaling Co. (Fessenden)

3 1=kw. transmitters:
U.S.S. *Illinois, Alabama* and *Dolphin.*

American De Forest Wireless Telegraph Co.

4 35=kw. transmitters:
Key West, Fla.; Guantanamo Bay, Cuba; San Juan, Puerto Rico; and Canal Zone.

1 10=kw. transmitter:
Pensacola, Fla.

1 2=kw. transmitter:
U.S.S. *Colorado.*

1 3.5=kw. transmitter:
U.S.S. *West Virginia.*

Telefunken Co.

1 6=kw. transmitter:
New Orleans, La.

2 3=kw. transmitters:
U.S.S. *Nebraska* and *Vermont.*

1 1=kw. transmitter:
Lightship Number 78

Massachusetts Wireless Equipment Co. (Pierce)

Three sets reported purchased. Specifications not given.

W. J. Clark Co.

One portable set for Guantanamo.

All of the above sets were supplied with at least one receiver.[73]

The Secretary of the Navy's report of 1906 contains this statement:

It is the policy of the Bureau to purchase different types of wireless apparatus from the various manufacturers in this country for installation in ships and shore stations, in order to encourage competition. It is believed that this method of procedure, together with the stimulus afforded by propective commercial profits, has produced a development of the art in this country equal if not superior to that attained abroad."[74]

The record supports the statement, for equipment was bought from practically all available manufacturers.

The 1906 "Wireless Stations of the World," issued by the Navy, lists the numbers of naval radio installations of that year as: Slaby-Arco and Telefunken, 51; Shoemaker, 21; De Forest, 9; Fessenden, 3; Stone, 8; Massie, 13; total, 105. This indicates that 48.5 per cent of the equipment in use was of German manufacture although by this time they were, to a large degree, composite sets. The original German transmitters had been modified to give a 500-cycle note, instead of the original 50-cycle one, by increasing the number of segments in the mercury turbine interrupter. This improvement was brought about by the experiments of a Navy operator named Woberton. The Slaby-Arco receivers had been modified in various manners and the coherers had been replaced by electrolytic or magnetic and, in some instances, by shipboard-made detectors.

[73] Ibid.

[74] Annual Report of the Secretary of the Navy, 1906, p. 50.

CHAPTER IX

Early Usage of Naval Radio

The organization of the U.S. Navy resulted in the division of naval radio into two almost separate components at its very beginning. One of these, the shore radio system, by the nature of the organization of the Shore Establishment, was a coordinated system under a control stemming down from the Secretary of the Navy. This organization was improved even more by the early adoption of the naval district organization wherein the commandants were responsible for all naval activities within their specified areas. The operators at these stations were given specific tasks to be performed at specific times and their work was under close scrutiny. Circuit discipline, although not as good as in later years, was exercised by the commandants and their staffs. Moreover, the establishment of the radio system took away none of the prerogatives of the commanders of the Shore Establishment, for they were already subject to the telegraphic orders of the Navy Department. In the case of fleet radio communications the stations in the ships were, of course, responsible to the commanding officer and through him up the chain of command. However, in comparison with the shore stations, the operators were poorly supervised and circuit discipline was practically nonexistent. The radio operators developed into a group apart, usually only answerable to the commanding officers, who, in most part, let them do as they pleased. Senior officers took it as a means of diminution of their powers and were apt to be somewhat like Lord Nelson at Copenhagen when he used his worthless eye on a signal he did not care to receive.

Mr. George H. Clark, the Navy's first civilian radio expert, and the one person best qualified to describe what must be called a sad commentary on fleet usage of radio, noted:

They sent to each other whatever and whenever they pleased. If one of them wished to send a message from their ship to some sweetheart ashore, the ship's wireless called the nearest shore station, prefaced his remarks "take a note, old man" and then sent his message of love, which was duly forwarded by telephone. Installations were not standard; that is even for a given type of set the installations could be changed around at the will of the chiefs, and this they did often and freely.

Speaking with the utmost candor, the older officer mistrusted, did not understand, and made mild fun of wireless. Out of my own experience I recall the remarks of one officer, who saw a flat-top antenna not yet drawn up taut and who remarked testily, "How can they expect to tune a thing like that when its strings are loose"; and of another who announced that finally he saw what was meant by "grounding" a set on a ship, because the water in the salt water pipes went down until they reached the ground (or, as I put it then, "to have a grounded set you need a grounded ocean") . . . Ensign Harold Dodd got his first assignment to wireless because he could play the piano, hence "knew how to tune a set." Even in the earliest days this antagonism was evident. When Admiral John Rodgers was head of the Wireless Telegraph Board testing American sets at the Highlands, he was present one day during tests with the U.S.S. *Topeka*. The coherer at the Highlands was very sensitive and started to jam; Jack Scanlin tried to tell the ship to reduce power, but unsuccessfully; finally he climbed the wireless mast and wigwagged the message to them. The Admiral, looking on, remarked, drily, "You had to go back to the old-time wireless after all, Scanlin."

As to the officers, they used the wireless for messages concerning their position and expected date of arrival at port, for data as to supplies, and in general, for an every-day telegraphic service by ether instead of wire. As to using this for tactical work, there was hardly any of this done. Nor were the commanding officers desirous of too close contact with Washington . . . the traditional power of a commanding officer to do as he felt best with his ship or command as soon as he got out of sight of land would have been completely wiped out if someone in the Bureau of Navigation or elsewhere could give him orders. So often the instructions to the wireless room were to shut down the wireless and not acknowledge calls from shore at all.[1]

Had gunnery, seamanship, or engineering been as subjected to the lack of interest and understanding as radio was, we would have had a fleet in name only. Had radar received this treatment in its infancy it would not have been one of the major contributors to the victories which brought the Axis Powers to their knees.

THE SHORE RADIO SYSTEM

With the responsibility for Government radio operations placed upon the Navy by President Roosevelt, the Bureau of Equipment immediately commenced to expand the shore system to meet the established requirements. Immediate action was taken to make it available to all Government departments and to all ships at sea, irrespective of nationality or of the type of equipment with which they were fitted.

"Instructions for the Transmission of Messages by Wireless Telegraphy, U.S. Navy, 1904," were promulgated on the same day that President Roosevelt approved the recommendations of the Interdepartmental Wireless Telegraph Board insofar as governmental usage was concerned. This 15-page publication, which had an effective date of 1 October 1904, superseded the "Instructions for the Use of Wireless Telegraph Apparatus" which had been prepared by Hudgins. It contained six pages of instructions for use of the system, and required that a continuous watch be maintained at all shore stations. The remainder of the publication provided information concerning the telegraphic codes and the call letters of ships and stations. At the time there were three separate telegraphic codes in use, the Navy or Meyer, the American Morse, and the International or Continental Morse. Naval radio operators were required to use all three of these.

To provide nonnaval personnel with the necessary information concerning the U.S. Naval Radio Service and instructions pertaining its free use, a separate bulletin was prepared. In order to obtain the widest possible maritime distribution for this, resort was made to a U.S. Naval Hydrographic Office periodic publication, "Notices to Mariners," which was widely used by merchantmen and always available at U.S. naval branch hydrographic offices located in all principal seaports. A "Special Notice to Mariners," issued under date of 22 November 1904, contained these instructions and the information and a notice that additional information of interest to mariners concerning the service would be included in its future editions.

This "Special Notice to Mariners" stated that U.S. naval radio facilities were available for the public, generally, and the maritime interests, in particular, for communicating with ships at sea, where not in competition with private radio facilities, for the purpose of:

Reporting vessels and intelligence received by radio with regard to maritime casualties, derelicts and overdue vessels;

Receiving radiograms of a private or commercial nature from ships as sea, for further transmission by telegraph or telephone systems; and, transmitting radiograms to ships at sea.

It also listed the locations and call letters of the available naval radio stations and contained instructions relative to the methods of payment of commercial charges to the telegraph and telephone companies. Information was provided concerning the transmissions of weather, dangers to navigation, and a proposed time service.

Following the promulgation of this bulletin, the Navy established the first organized radio aid for navigation and safety of life

[1] "Radioana," Massachusetts Institute of Technology, G. H. Clark, "Radio in War and Peace, unpublished manuscript, n.d., pp. 65-66.

at sea service in this country. The regulations and information promulgated have remained applicable to this day and remain the basis for the provision of such services. This "Special Notice to Mariners" is reproduced as appendix E.

ORIGINS OF SPECIAL BROADCASTS OF THE NAVAL RADIO SERVICE

After issuing its "Instructions for the Transmission of Messages by Wireless Telegraphy," the Navy Department, on 30 November 1904, directed all naval shore radio stations to promptly transmit all weather reports and storm warnings, provided by the Weather Bureau, on designated schedules. Additionally, they were directed to transmit hurricane information as soon as warnings were received as well as on the regular schedules. All U.S. naval vessels fitted with radio were directed to transmit meteorological observations, addressed to the Weather Bureau, at least once daily or oftener when storm conditions existed.[2] The times of the specified weather schedules were published in the December issue of "Notices to Mariners."

In 1906 the masters of approximately 50 ships agreed to provide the Weather Bureau with radio messages containing weather observations once daily, at a specific time, when within certain prescribed ocean areas. Mostly, these were passenger ships plying North Atlantic routes, but there were a few in the South Atlantic and Caribbean areas and one in the Pacific, the SS *President*, said to be the only merchant ship in that ocean fitted with radio as of 18 June 1907. A report from the SS *Cartago* of 26 August 1906, off the coast of Yucatan during a hurricane, is credited as the first from a ship to be used in connection with the issuance of such warnings.[3]

The increasing number of the Navy's radio installations enabled the Weather Bureau to obtain information from constantly widening sources, thereby increasing the reliability of the reports. The contributions of this service to the safety of life at sea have been and continue to be inestimable and have been fully justified by the saving of life and property.

With exact time being of the utmost importance in celestial navigation, the Navy realized at the very beginning of the establishment of the shore radio stations the desirability of providing a scheduled broadcast of exact Naval Observatory time. In September 1903 experiments were commenced with the short-range, low-powered radio transmissions of time signals from the station at the Highlands of Navesink, N.J.[4] On 9 August 1904, the first official scheduled transmission of such signals was started at the radio station of the Boston Navy Yard. This was the beginning of the worldwide service now rendered by the naval communication system.

When the order was received at Boston to begin broadcasting time signals, no automatic relay was available to the station, so they were unable to let the impulses from the landline automatically key the transmitter. As the "time clicks" arrived the operator attempted to keep an even pace with them with the unwieldy key fitted to the Slaby-Arco transmitter. This resulted in a slight timelag due to the delay in translating thought into manual action. It was feared that the error in the chronometer rate obtained from the use of these signals might nullify their usefulness. This error was eventually eliminated by the use of instantaneous automatic relays.

During 1904 the stations at Cape Cod, Mass., and Norfolk, Va., were directed to transmit time signals and, during the next year, Portsmouth, N. H., Key West, Fla., and Mare Island, Calif., were added to the list. Since the reliable range of these trans-

[2] E. B. Calvert, "History of Radio In Relation to the Work of the Weather Bureau," Monthly Weather Review, January 1923, (Government Printing Office, Washington, 1923), p. 1.

[3] Ibid., p. 4.

[4] J. F. Hellwag, "United States Navy Time Service," Astronomical Society of the Pacific, vol. 52 (1940), p. 17.

missions was about 50 miles, they were only of aid to vessels near the coast. By 1909 the number of stations transmitting time signals had been increased to 19 and the reliable range to about 100 miles. This service was another which enhanced the safety of lives at sea by affording more accurate navigation for those approaching land. No other country attempted to broadcast time signals until 1927.[5] Improvements in this service continued apace with the improvements in radio until eventually ships were able to receive these transmissions regardless of the ocean in which they sailed.

Another important aid to maritime security was instituted by the U.S. Navy on 7 August 1907, when an item was included in the "Notices to Mariners" stating that radio warnings of obstructions dangerous to navigation would be broadcast three times daily by naval radio stations. In addition to the positions of obstructions such as icebergs and derelicts, these broadcasts contained information concerning lightships off station and lighthouses with extinguished lights.[6]

The Bureau of Equipment issued the first international call book of radio stations in 1905. This was prepared under the direction of Lt. J. J. Hyland, USN, and was titled, "List of Wireless Telegraph Stations of the World." [7]

A few years after the initial publication of the "Instructions," the "Manual of Wireless Telegraphy for the Use of Naval Electricians," frequently referred to as "Robison's Manual," was issued. Robison, during his tour of duty as head of the Radio Division, assisted by J. L. Jayne, prepared this manual in 1905. It was first published in January 1907. For approximately 25 years it was, with revisions, recognized as the Navy's standard textbook on the subject.

[5] Wireless World, (Dorset House, Tudor St., London E.C. 4, England), 28 Dec. 1927, p. 843.

[6] Annual Report of the Secretary of the Navy, 1908, p. 317.

[7] L. J. Haslett, "Some Notes on the Eearly History of the Radio Division," Radio and Sound Bulletin, July 1, 1944 (Navy Department, Bureau of Ships), p. 6.

TRAINING IN THE STRATEGIC USE OF RADIO

It was not until 1906 that any effort was made to train fleet personnel in the use of radio for strategic purposes. Failure to conduct exercises for this purpose was the result of a totally inadequate radio operator training program, both in number and in scope. The Bureau of Navigation, responsible for the training of naval personnel, could or would not understand why ordinary signal training was not sufficient and took no positive steps until forced to do so by the Secretary of the Navy after numerous criticisms of its inactivity and the paucity of personnel for the maintenance and operation of radio equipment.[8]

Early in 1906, Rear Adm. Robley D. Evans, USN, Commander in Chief of the U.S. Atlantic Fleet, set up a simulated search problem en route from Hampton Roads, Va., to the Caribbean area. Shortly before this, the floating drydock *Dewey*, which had been constructed in the United States, had departed under tow for the U.S. Naval Base, Cavite, Philippine Islands, via the Suez Canal. Evans decided to use this as the target for his search since it would also afford the commander of the towing group a means of relaying his messages back to the United States.[9]

Upon departure from the United States, Admiral Evans established his scouting line to the eastward of his main body. The latter was to maintain a direct course from the

[8] Letter, dated 6 Feb. 1904, Acting Chief of the Bureau of Equipment to the Bureau of Navigation, files, Bureau of Equipment, National Archives, Washington, D.C.; Letter, dated 15 Feb. 1904, CO U.S.S. *Kearsage* to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[9] Letter, dated 13 Jan. 1906, Commander in Chief, U.S. Atlantic Fleet, to Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

Virginia Capes to Culebra, West Indies. The scouting line was composed of five ships, in order from the main body eastward, U.S.S. *Illinois, Pennsylvania, West Virginia, Colorado,* and *Maryland.* The scouting interval was varied dependent upon the ability of the scouts to maintain radio communications with adjacent vessels on the line.[10]

Late on 19 January, when the *Maryland* was 500 miles east of Cape Hatteras, N.C., 600 miles north of San Juan, P.R., and 640 miles west of the U.S.S. *Glacier,* flagship of the towing expedition, she received a message from the latter for relay to Washington. This was relayed to the U.S.S. *Missouri,* in the main body via the *Illinois.* The *Missouri* passed it on to the U.S.S. *Maine,* Evans' flagship, by visual methods. The *Maine* endeavored to relay this to a shore station but was unable to obtain a receipt.

Some 40 hours later with the main body about 300 miles further south another message was relayed via the scouting line to the *Missouri,* relayed visually to the *Maine,* and broadcast by her to the shore stations. These were the only two transmissions relayed from the *Glacier,* although the *Maryland* maintained fairly good communications with her for several days.[11]

During the trip constant endeavors were made to maintain communications between the ships of the scouting line and the main body, but with exceedingly poor results.

In his preliminary report of the exercise Evans wrote:

> The vagaries of the wireless instruments do not seem to be fully understood as yet, for at times when there seem to be no atmospheric electricity present the nearest scout could not be heard by any one of the First Squadron, but at other times they have picked up messages apparently passing between the Dock and the *Maryland.*[12]

The final report, signed by Evans, contained an analysis of radio operations which, in substance, is stated below.

There were numerous instances in which atmospheric disturbances interfered with the scouts reception of messages from each other, some periods being of 12 to 14 hours' duration, and occurring to most of the ships alike, except in case of the *Maryland,* with a radio transmitter of such power that atmospheric electricity interefered with the reception of her transmissions very little. The *West Virginia,* having a set next in power to the *Maryland,* was best able to keep in communication with all the remaining ships. There were instances when all the vessels intercepted messages from ships many hundreds of miles distant and messages from the *Colorado* to the *West Virginia* were read by the *Maine,* and even fragments of messages from the *Glacier* to the *Maryland,* but, as a rule, with the exception of the *Maryland* and the *West Virginia,* with the *Illinois* third, static interference affected all alike. There appeared to be a great difference in the delicacy of the receiving instruments, as well as in the power of the transmitters, with both being subject to variation for long periods of time. At one time the *Maine* could receive nothing from the *Illinois,* then only about 200 miles distant, and at the same time her transmitter was the only one powerful enough to transmit to her. In this case when the *Illinois* called the flagship, one of the other vessels would inform her, whereupon the *Maine* would answer, the other vessel receiving and the *Maine* acknowledging. All ships experienced interference from the transmissions of other vessels. Even the *Maryland,* nearest the *Glacier,* at times would have a message broken up through interference of vessels further to the westward and at

[10] Letter, dated 13 Jan. 1906, Commander in Chief, U.S. Atlantic Fleet, to Commander, 4th Division, U.S. Atlantic Fleet, files, Bureau of Equipment, National Archives, Washington, D.C.

[11] Letter, dated 22 Jan. 1906, Commander in Chief, U.S. Atlantic Fleet, to the Secretary of the Navy, files, Office of Naval Records and Library, series RG 45.

[12] Letter, dated 2 Feb. 1906, Commander in Chief, U.S. Atlantic Fleet, to Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

a long distance from her. There were causes other than interference which prevented the ships from receiving messages; the *Maryland* tried for hours to call the *Colorado,* and finally contacted her and transmitted a message to her 12 times, and in 1 repetition each word was repeated 3 times, but no acknowledgment was received from the *Colorado.* Finally, after these attempts, the *Maryland* called the *West Virginia,* then about 550 miles distant, and the latter ship relayed the message. The *Maryland* could both transmit and receive messages under good conditions for a distance of 600 miles, but if the adjacent vessel lacked the power to acknowledge receipt of messages, even if she heard them, the value of the power of the *Maryland's* apparatus was lost. The *Colorado* and the *Pennsylvania* had ranges of about 150 miles, and the *West Virginia* probably about 300 miles. Errors frequently occurred that became quite serious at times, such as when operators gave positions and courses incorrectly by failing to spell out numerals in an attempt to speed up transmission.[13]

This is a confusing analysis and thoroughly indicates the lack of knowledge and appreciation of the capabilities of the installations. Efficiency of installation was confused with power as indicated by the following table of equipments:

Ship	*Transmitter*		*Receiver*
Maine	Slaby-Arco	1.25 kw	Shoemaker
Missouri	Slaby-Arco	1.25 kw	De Forest
Maryland	Shoemaker	1.25 kw	Shoemaker
Colorado	De Forest	2.00 kw	De Forest
Glacier	Slaby-Arco	1.25 kw	Slaby-Arco
West Virginia	De Forest	3.50 kw	De Forest
Illinois	Fessenden	1.00 kw	Fessenden

It will be noted that the *West Virginia* was fitted with the most powerful transmitter; the *Illinois* with the least powerful. The remainder of the ships, except the *Colorado,* were fitted with transmitters of the same power. The *Maine,* equipped with the same type receiver as the *Maryland* and *West Virgina,* did not obtain as good results as the latter two. The transmissions of the *Colorado,* with her 2-kw. De Forest transmitter, apparently were difficult to receive. The *Illinois,* fitted with the same type of equipment as the U.S.S. *Alabama,* which at this time was having considerable trouble with its radio plant, was given an efficiency surpassed only by the *Maryland* and *West Virginia.* The fact that some of the ships were able to maintain communications with each other for long periods of time and yet not with others would indicate that they were better tuned to the 700-kc frequency in use. Undoubtedly some of the operators were more capable than others and it is possible that better officer supervision may have existed in some ships. The one glaring deficiency, as indicated by the wording of the analysis, was the lack of understanding of the workings of the apparatus and that sufficient training was still not being provided. Although some knowledge existed concerning the directivity of radio transmissions, no effort was exerted to make practical use of this. It is quite possible that during some of the extended periods in which no reception was possible the ships were on unfavorable headings.

In concluding his report Evans commented to the effect that radio could not be used with certainty between ships of a scouting line nor between the scouting line and the main body. The uncertainty could be reduced considerably if two ships occupied a single station on the line and if its advance was paralleled by a movement of the main body in order that the latter always remain relatively close.[14]

A month later another exercise was conducted simulating the conditions which had existed the previous August when the Russian battleships sortied from Port Arthur in an attempt to escape the Japanese Fleet. The Blue (Russian) Force consisted of the U.S.S. *Alabama, Illinois, Maine, Missouri, Kearsage,* and *Iowa* while the

[13] Ibid.

[14] Ibid.

Red (Japanese) Force was composed of the U.S.S. *Maryland, West Virginia, Pennsylvania,* and *Colorado.* One facet of this exercise called for the Blue force to endeavor to prevent the Red scouting line from communicating with each other and with the main body by creating radio interference.[15] Unfortunately the two ships selected to provide the interference were the *Fessenden*-equipped *Alabama* and *Illinois,* both of which were having troubles with their equipments in tropical waters. However, between them they did manage to keep one transmitter at a time operating almost continuously. When within a few miles of the *Maryland,* representing the Red main body, they were able to interfere with her reception but her transmission[15] could be copied by the scouts on the line except at such time as the distance between the main body and the closest scout was reduced to a few miles. The critique which followed the exercise adjudged that the Blue Force had failed to disrupt the communications of the red force and that the latter's scouting line had been able to provide its main body with the Blue Force's changes in courses and speeds. This is also a confused report and appears to indicate that it was believed that the best position for creating interfering radio reception was close to the transmitting vessel.

The radio personnel of the *Alabama* and *Illinois* had a difficult maintenance job during the period these ships were providing the interference. Transmitting with maximum power caused excessive heat which resulted in cracked condenser plates and burned out transformers. These were repaired by spare pilothouse window glass, pieces of sheet zinc, and tinfoil taken from tobacco packages. Blowers had to be jury rigged to provide air jets to dissipate the heat generated in the radio room.[16]

[15] Letter, dated 3 Feb. 1906, Commander in Chief, U.S. Atlantic Fleet, to Commander, 4th Division, U.S. Atlantic Fleet, files, Bureau of Equipment, National Archives, Washington, D.C.

[16] Letter, n.d., Commander in Chief, U.S. Atlantic Fleet, to the Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

No endeavor was made to utilize radio for tactical purposes during these exercises nor during this year. The procedures for such use had been established,[17] but commanders were wary of its use for maneuvering in close formations and of its ability to withstand the shocks of battle.[18] In fact, following these two exercises, radio, insofar as the fleet was concerned, became more and more a seaward extension of cable and telegraph facilities and so remained for several years.

AID RENDERED BY NAVAL RADIO FOLLOWING THE SAN FRANCISCO EARTHQUAKE

The U.S.S. *Chicago* departed San Francisco on the evening of 17 April 1906. Early the next day that city was in the center of the most disastrous earthquake this Nation has ever suffered. The damage from it and the fires which followed destroyed much of this western metropolis. Upon learning of the disaster the rear admiral on the *Chicago* directed her return to port to render all possible assistance. Among other aids she provided the only rapid means of communication from the stricken area. Past Midshipman Stanley C. Hooper,[19] USN,

[17] "Instructions for the Transmission of Messages by Wireless Telegraphy, U.S. Navy, 1904."

[18] B. A. Fiske, "War Signals," U.S. Naval Institute Proceedings, vol. XXIX, no. 4, Dec. 1903, p. 932.

[19] Stanley C. Hooper was born, 16 Aug. 1884, at Covina, Calif. He was appointed to the U.S. Naval Academy from California from which he graduated in 1905. After 7 years of sea duty he returned to the Academy as an instructor in electricity, radio, physics, and chemistry. He was appointed Fleet Radio Officer in 1912. While serving in that position, he participated in the occupation of Veracruz. Following the outbreak of World War I, he was sent to Europe as a radio observer. On completion of that tour of duty he served as Head of the Radio Division of the Bureau of Engineering (now Bureau of Ships). During this time he was made a member of the first Board of Organization of the Naval Communication Service. In 1917 he commanded the U.S.S. *Fairfay,* and for distinguished service, during this duty he was awarded the

a young officer, who had had some experience in telegraphy as a summer vacation operator at a country station of the Southern Pacific Railroad, was then serving on the *Chicago*. During this incident, he gained his first naval radio experience and from this he was to go on and eventually gain the appellation, "Father of Naval Radio." This work is dedicated to him and to others who aided in building the effective system which was available at the beginning of World War II.

Since he was there, the story of the *Chicago's* part in providing a rapid communication channel from San Francisco following the disaster is best told by quoting from his memoirs:

> There is not much to say about the *Chicago*. She did have a radio set because she was a flagship, but it was not of much use because its range was less than 100 miles . . . I did learn a little about the apparatus but was not allowed to operate it. That was the sacred job of the radio operator and the radio was under the Flag Officer, so ship's officers keep discreetly clear.
>
> All radio sets in those days made a lot of noise and could be heard the length of the ship and further. I was able to read the signals which were transmitted even though I did not go into the operating room. It seemed they used a slightly different code than I was used to in railroad telegraphing but listening carefully I was able to learn the differences and found that seven of the letters were different. Soon I became accustomed to those differences and became qualified in Continental as well as American Morse code.
>
> One day the *Chicago's* radio became very important in an emergency. We had put to sea from San Francisco in the late evening and at five in the morning the operator received a message that there had been a terrible earthquake in San Francisco and that the city was ablaze. The Admiral immediately ordered us back and by ten that morning our ship was docked near the Ferry Building and the crew landed to help fight the fire and curb looting. The Western Union and Postal Telegraph wires were all down and it was decided to use the *Chicago's* radio as an outlet for all priority messages, by relaying them to the radio station at Mare Island from which place they could be telegraphed. There was no one available to take charge of this project who knew anything about the telegraph business. The officers were assembled in conference and the question was asked as to where we could locate a person possessing this knowledge. I stepped forward and meekly admitted my small experience as an operator at a small railroad station and two hours later found myself installed in the Wharfingage Building by the docks in charge of all outgoing messages. The Army Signal Corps sent an officer to cooperate and he established field circuits from seven different zones within the city. Messenger service was established between the office and the radio station on the ship just half a block away. Thus it was, that all through the emergency, until the cables were repaired a few days later, I, a young past-midshipman, had charge of all the outgoing telegraph business of San Francisco during that disastrous period.[20]

The Navy radio stations played a major

Navy Cross. From 1918 to 1923 he was again Head of the Bureau of Engineering's Radio Division. He served as U.S. Fleet Radio Officer during 1923-25, after which he again became Head of the Radio Division. In 1927, in addition to his regular duties, he was appointed Technical Adviser in Charge of Engineering for the Federal Communications Commission. He was appointed Directer of Naval Communications in 1928 and remained in that capacity until 1934. During this period he was a member of the President's Radio Board. During the period 1915 to 1928, Hooper was the guiding spirit in developing naval radio from little more than a toy to the essential communication medium it became. Under his direction and influence, many new features, such as the radio direction finder, appeared as standard in naval radio equipment. For many years he represented this country's Government radio interests in practically all international radio conferences. He originated the recommendation which resulted in formation of the Radio Corp. of America, thus creating an all-American worldwide communications company, to free the United States from dependence on foreign-controlled radio communications. He served as Director of the Radio Division under the Chief of Naval Operations from 1939 until appointed in 1942 as Technical Assistant to the Vice Chief of Naval Operations. He was transferred to the retired list as a rear admiral, on June 1, 1945. Besides a number of military awards, Admiral Hooper was recipient of the Elliott Cresson Gold Medal, given by Franklin Institute for his "discovery of original research, adding to the sum of human knowledge, irrespective of commercial value," and the Marconi Memorial Medal of Merit "for outstanding contributions to the radio art, particularly in building up the communication system of the United States Navy from the status of an engineering experiment to a major military arm for control, detection, and communication." He died on 6 Apr. 1955 in Miami, Fla.

[20] S. C. Hooper "Navy History—Radio, Radar, Sonar," 2R4, p. 10 (Naval History Division, Washington, D.C.), unpublished manuscript, n.d.

role in providing this means of remaining in touch with the outside world. As soon as it was realized that this was the city's sole rapid contact with the outside, they were flooded with messages from military and municipal authorities and the general public. In about 2 weeks the *Chicago* sent and received over 1,000 messages. The naval radio station on Yerba Buena Island was fully occupied acting as a relay between the *Chicago* and the station at the Mare Island Navy Yard which provided telegraphic connection with the rest of the country. The radio station on Farrallone Island provided the means for directing the shipping headed to the stricken port.[21]

[21] Electrical World, (McGraw-Hill Co., New York), 2 Apr. 1906, p. 1110.

CHAPTER X

Renewed Efforts to Establish Control

INCREASE IN RADIO INTERFERENCE

Earlier efforts and failures to establish Federal regulation of the use of radio have been related.[1] Interference between Government, commercial, and amateur stations continued to increase rapidly. Operators at the various commercial stations endeavored to prevent each other from transmitting traffic. Many amateurs intentionally interfered with the receipt of both Government and commercial messages. A chaotic situation existed. The question of Federal regulation was again brought to the front when, in 1906, President Roosevelt became a victim of the situation. Interference in the Boston area made it necessary to dispatch a torpedo boat to the drill grounds off Cape Cod, Mass., to deliver messages to him in the *Mayflower*. As a result of this incident, Rear Adm. Robley D. Evans, Commander in Chief, U.S. Atlantic Fleet, was verbally instructed by him, on 29 September, to prepare a memorandum regarding radiotelegraphy and recommendations as to its control. In compliance he submitted the following:

MEMORANDUM FOR THE PRESIDENT

1. Government wireless stations on the sea coast were placed under the control of the Navy Department by Executive Order dated July 29, 1904.

2. There are many commercial stations along the coast that are more powerful than those now in use on naval ships: If their instruments have approximately the same wave lengths as ours, they interfere to such an extent as to prevent completely the sending or receiving of official messages. Many of them will give way to official messages, but there are many wireless stations (the Marconi stations particularly) that, neither give way to official messages nor refrain from breaking in when messages are actually being transmitted.

3. Where two or more commercial companies have wireless stations in the same vicinity they interfere with each other, and only by a common agreement can each carry out its business.

4. Generally speaking, stations using instruments of a long wave length do not interfere with those using shorter waves; as for instance, the long distance station at Wellfleet, Mass., does not materially interfere with naval vessels. As soon as naval long distance stations are installed in the same vicinity, as may soon be necessary, this station and similar ones will also interfere unless, it, with all others on the coast, are under a common control.

5. The Naval Service, as well as commercial interests, demands the use of wireless telegraphy for all distances possible across the water. As it is impracticable to prevent wireless interference, when any one who may so desire can establish a station of any power or any wave length and send messages at any time in the day, it is obvious that, for the common good, the Government, which represents the whole Country, should regulate all the wireless stations along the coast.

6. I have therefore to recommend the following:

(a) That, all coast wireless stations shall be under the control of the Navy Department.

(b) That, these stations may be connected by special wires to the commercial telegraph lines and shall be used for commercial messages between the shore and ships at sea; under such regulations as the Secretary of the Navy may prescribe.

(c) That, no private wireless stations shall be permitted inland, the power of which is sufficient to send a message to the sea coast.

(d) That, the Secretary of the Navy shall be empowered to cause to be inspected any private wireless station, and, in the event of it being found by this inspection that this law has been disobeyed, he shall take immediate steps to have such station closed by due process of law until the wireless apparatus has been brought to conform to the law.[2]

[1] Supra, ch. VII.

[2] Files, Bureau of Equipment, National Archives, Washington, D.C.

REVERSAL OF THE BUREAU OF EQUIPMENT POLICY PERTAINING TO FEDERAL REGULATION

At this time, after having gained the complete support of the Executive Branch of the Government in the struggle to obtain legislation controlling the use of radio, the Bureau of Equipment took a position which is difficult to understand. Commenting upon Evans' recommendations, it stated, in effect, that it was essential, both in times of peace and of war, that there be a chain of intercommunicating radio stations along the coasts of the United States and between it and its outlying possessions. Additionally, for the purposes of aiding navigation, intermediate stations should be located at each lighthouse and that several long-distance circuits should be established for the purpose of communicating with the fleet at the maximum possible distance. In the foreseeable future, it considered that commercial limitations were such that this could only be accomplished and maintained by the Government and, being of this opinion, the Bureau had established a chain of stations on the east and gulf coasts with intercommunicating stations in the West Indies and Panama, was in the process of establishing a chain on the Pacific coast, and was preparing for the establishment of a chain in the Philippines.[3]

Concerning the problem of interference and its control, the Bureau expressed the opinion that experience had already demonstrated that interior radio communication was impractical and that any attempt to establish this on a commercial scale would fail. Therefore, it considered the only available commercial radio field was in the provision of communications between ships at sea, between ships and shore, and cross bodies of water. This type of business might, and probably would, be remunerative to a single company and thus it appeared that, in the near future, there would be but one company maintaining radio communications for public service. When this came to pass arrangements could then be made with that company for the prevention of interference. After that it would only be necessary to regulate the operation of experimental and private stations, without interfering with vested commercial rights. The policy of the Bureau to encourage the commercial use of radio and to encourage private experimental work had resulted in rapid development of the art in the United States, and it deemed that, for the time being, at least, it was not desirable to restrain the working of such stations afloat or ashore. The decisions of the International Conference on Wireless Telegraphy, then in session in Berlin, would have an important bearing upon matters relating to ship-to-ship and ship-to-shore communications. The Bureau concluded its remarks by recommending that no immediate action be taken to regulate the operation of commercial radio stations, hoping that, before long, it could bring about the desired control of radio.[4]

THE SECOND INTERNATIONAL RADIO TELEGRAPHIC CONFERENCE, BERLIN, 1906

In May 1906, the Chief of the Bureau of Equipment made comments concerning the International Radio Telegraphic Conference scheduled to be held in Berlin in October. The first of these recommended the acceptance of the invitation.[5] Since the President's approval of the recommendations of the Interdepartmental Wireless Telegraph Board had placed the control of all Government coast radiotelegraph

[3] Letter, dated 22 Oct. 1906, Bureau of Equipment endorsement on Commander in Chief, U.S. Atlantic Fleet, letter, dated 9 Aug. 1906, files, Bureau of Equipment, National Archives, Washington, D.C.

[4] Ibid.

[5] Letter, dated 14 May 1905, Chief of the Bureau of Equipment to Comdr. F. M. Barber, USN (retired), files, Office of Naval Records and Library, National Archives, Washington, D.C.

stations under the Navy Department, the Bureau recommended that Rear Adm. H. N. Manney, USN, lately retired, and Commander Barber be designated as the Navy Department's representatives at the Conference, and that Manney be designated the head of the U.S. delegation.[6] No legislation having been enacted on the subject, the Bureau favored an interdepartmental conference to draw up instructions for the delegation and that these instructions should be considered as expressing this Government's attitude. The Bureau made several suggestions as to how the delegates should be instructed. The first was that they advocate the international adoption of sections 2 and 3 of article I of the final protocol of the 1903 Conference. These required coastwise stations to receive and transmit radiograms originating on ships at sea without distinction as to the make of equipment employed and that contracting States make public any technical improvements which would facilitate such communications. Secondly, that, as an important aid to navigation, it was further recommended that they advocate an extension of the weather reporting services of all countries, in accordance with recommendations of the Interdepartmental Wireless Telegraph Board. The third was a recommendation for an extension of the use of the International Signal Book to radiotelegraphy, with the letters for "International Code" to be given international recognition, on a call for that code, in the same way that the code pennant was then used. Those letters were not to be assigned as a "call" to any shore station or vessel in any country.[7]

The suggestion of appointing an interdepartmental board to arrive at a U.S. position was accepted, and one was ordered to convene in Washington during May 1906. Having been designated by the Secretary of the Navy as the delegate of the Navy Department to the International Conference, Admiral Manney was also appointed the Navy's representative at the meeting of this Board.[8]

As finally constituted, the American delegation consisted of Ambassador Charlemagne Tower, head of the delegation; Rear Adm. Henry N. Manney, USN (retired); Brig. Gen. James Allen USA, Chief Signal Officer of the U.S. Army; Mr. John I. Waterbury, Department of Commerce and Labor; and Com. F. M. Barber, USN (retired), who was appointed technical secretary to the delegation. For Waterbury and Barber it was a repeat performance, both having been delegates to the 1903 Conference. The delegates took with them to the Conference a mass of statistics showing the work done by the Navy Department in the development of radio during the 3 previous years.

Pursuant to the invitations issued by the German Government, the Second International Radio Telegraphic Conference finally convened at Berlin on 3 October 1906. This Conference had originally been scheduled for 1904 but Great Britain and France requested postponement in order to examine the material to be submitted. Germany agreed to this postponement and suggested 4 April 1905 as the convening date. By that time Russia and Japan were engaged in conflict. Later, a convening date of 28 June 1906 was established, but another delay was requested by Great Britain. One

[6] Letter, dated 16 Jan. 1905, Chief of the Bureau of Navigation to Comdr. F. M. Barber, USN (retired); letter, dated 15 Aug. 1906, Chief of the Bureau of Equipment to Chief of the Bureau of Navigation; letter, dated 21 Aug. 1906, from Secretary of the Navy to Rear Adm. H. N. Manney, USN (retired), files, Bureau of Equipment, National Archives, Washington, D.C.

[7] Letter, dated 5 May 1906, Acting Secretary of the Navy to Rear Adm. H. N. Manney, USN (retired); letter, dated 30 Apr. 1906, Assistant Secretary of Commerce and Labor to Secretary of the Navy; letter, dated 10 May 1906, Secretary of the Navy to Rear Adm. H. N. Manney, USN (retired), files, Bureau of Equipment, National Archives, Washington, D.C.

[8] Letter, dated 10 May 1906, Secretary of the Navy to Rear Adm. H. N. Manney, USN (retired); letter, dated 14 May 1906, Chief of the Bureau of Equipment to Comdr. F. M. Barber, USN (retired), files, Bureau of Equipment, National Archives, Washington, D.C.

hundred and nine delegates and functionaries represented Germany, the United States of America, the Argentine Republic, Austria, Hungary, Belgium, Brazil, Bulgaria, Chile, Denmark, Spain, France, Great Britain, Greece, Italy, Japan, Mexico, Monaco, Norway, the Netherlands, Persia, Portugal, Rumania, Russia, Sweden, Turkey, and Uruguay. Whereas the 1903 Conference had the representatives of 8 powers, this one was attended by delegations from 27 nations.[9]

By formal arrangement, adopted at the first of the 26 sessions, it was voted that the proceedings would be secret, therefore only accredited members were admitted to the conference rooms of the Imperial Reichstag.[10]

The initial discussions were for the purpose of determining the subjects to be contained in the Convention itself, as well as in the Rules and Regulations to be appended to it. These were induced largely by the difference in point of view and the variance in individual interests as well as in the geographical situation of the participants in the discussions. The attitude of the United States, as declared at the outset and maintained throughout the debates, was distinctly in support of unrestricted interchange of communications between all stations, without regard to the make of radio equipment used by any. It was evident from the beginning that countries such as Great Britain and Italy, which had already entered into contracts with the Marconi interests, based upon the exclusive use of their equipment and which prohibited interchange of messages with stations equipped with other than Marconi apparatus, could not readily agree to such a proposal. This caused difficulty in adjusting the differences of interests that were involved. The first focal point of variance was Article 3 of the Convention, the principle of which was that coastal stations and ship stations would be obliged to interchange messages with each other without distinction as to the apparatus used. Adoption of this would necessitate a violation, by several nations, of contracts executed between them and the Marconi interests. Although this article was finally accepted in principle, a vote upon it was postponed, at the request of Great Britain, until after the other articles of the Convention and of the Service Regulations had been discussed, adopted, or rejected. The U.S. delegation, considering it good policy to acquiesce to this postponement, gave notice that it did not modify its views concerning the principle involved. As the many other articles were discussed and amended from day to day in the sessions of the Conference, the delegation of the United States became concerned lest amendments might be introduced aimed at weakening the provisions of article 3 and nullifying its value even before it came up for final debate. To forestall such action, it made the following declaration:

The proceedings of this Conference have reached a point at which the delegates representing the United States of America find themselves obliged to make the following declaration:

"The acceptance of Article 3 in the terms proposed to the Conference is in their opinion indispensable to the due consideration of the Convention submitted to our deliberations. Its incorporation into the Convention without modification is necessary in order that that article may serve as the basis of an international agreement.

"The only objection which has been made to the provisions of this article is the assertion that the different systems of radio telegraphy are not able to communicate effectively one with the other; and, further, that all well organized systems already installed are susceptible to disturbances.

"It has been fully demonstrated by the Government of the United States of America, through experiments carried out in climates of every kind, that the different systems of radio telegraphy can be effectively used simultaneously one with the other. In fact, a combination made by selecting amongst the elements of different systems of radio telegraphy has produced better results than those which any one system has been able to give by itself.

"The United States Navy is actually using at present eight different systems in its coastal stations and its stations aboard ship; and during the three years in which it has been making these experi-

[9] "The Convention Adopted by the Second International Radio Telegraphic Conference," Berlin, Germany, 1906 (app. F).

[10] Ibid.

ments it has reason to be entirely satisfied with the results obtained.

"As to the questions of interruptions between one station and another, we have been able to operate without interruption telegraph stations in the immedaite vicinity of others having a different system of radio telegraphy, whilst stations close to each other although equipped with the same system of installation have not succeeded in securing freedom from disturbances.[11]

This declaration brought forth a flood of polemics that rocked the chamber, but resulted in article 3 being immediately floored for final debate. The British delegation exerted its strongest effort to defeat it, but, with the vigorous support of the United States and Germany, it was adopted without alteration. Since it was impossible for the British to accept the provision without violating the conditions of their Government's contract with Marconi, its delegation intimated that it could not remain at the Conference under such conditions. The Conference then agreed that an easement in the final protocol, in the form of an article, might be inserted for the sole purpose of permitting such nations as were involved with the Marconi interests to adhere to their contracts.[12] This provided that each contracting government could reserve to itself the right to designate, according to the circumstances, certain coastal stations which should be exempt from the obligations imposed by article 3 of the Convention, provided that, as soon as the measure went into effect, there should be opened, within its territory, one or more stations subject to the obligations of article 3, and insuring, within the region where the exempted stations were located, such radio service as would satisfy the needs of the public. Those governments which desired to reserve that right were to give notice thereof, by the form provided by the Convention, not later than 3 months before the Convention was scheduled to go into effect, or, in the case of subsequent adhesion, at the time of such adhesion. At the same time it was also agreed that those governments which did not wish to avail themselves of this reservation should formally declare that they would not do so. This declaration was intended as a show of hands and was signed by two-thirds of the represented nations. These were Germany, the United States of America, the Argentine Republic, Austria, Hungary, Belgium, Brazil, Bulgaria, Chile, Greece, Mexico, Norway, the Netherlands, Rumania, Russia, Sweden, and Uruguary.[13]

Having led in the successful campaign to insure compulsory radio communication between ships and shore stations, the next task which devolved upon the Americans was to assure intercommunication between ships, regardless of apparatus employed. Technically, only matters related to or included in the final protocol of the 1903 Conference were open to discussion in this one. That protocol contained no provision on the subject of compulsory intercommunication between ships. The President of the Conference, Herr Von Kraetke, Secretary of State for the German Postal Department, was reluctant to enter upon consideration of the subject, characterizing it as a new matter and hence one which could not properly be presented. The persistent, determined, and united opposition on the part of countries involved in Marconi contracts presented quite an obstacle to be surmounted, but the American delegation was equally persistent and determined. In this connection a quotation from one of the Manney's reports to the Chief of the Bureau of Equipment well illustrates the point:

Also the American delegation because of the policy of the Marconi Company in refusing to permit vessels equipped with Marconi apparatus to communicate with vessels equipped with other wireless ap-

[11] Letter, dated 17 Nov. 1906, Ambassador C. Tower to the Secretary of State, files, Bureau of Equipment, National Archives, Washington, D.C.

[12] Letter, dated 25 Nov. 1906, Rear Adm. H. N. Manney, USN (retired), to the Chief of the Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[13] Letter, dated 17 Nov. 1906, Ambassador C. Tower to the Secretary of State, files, Bureau of Equipment, National Archives, Washington, D.C.

paratus, as instanced in the case of the steamer *Vaterland* refusing maritime information to a government vessel to assist her in her search for a derelict, and the more outrageous instance of a Marconi station interfering to prevent communication between a U.S. Government vessel that had suffered loss in a storm and desired to send notice to the authorities, and an American Merchant steamer; on the ground that the wireless instruments on the government vessel was not of the Marconi system, submitted to the Conference Amendment #75 requiring general intercommunication between stations regardless of the wireless system employed in them.[14]

The delegation held that the principle of requiring ships to intercommunicate regardless of their make of radio equipment was of first importance to maritime interests and urged it in the Conference on the basis of commercial advantage, although it was chiefly concerned with it as a humanitarian measure.[15]

This ship-to-ship compulsory intercommunication proposal aroused the same, but a more hostile, opposition as that which had attempted to defeat article 3. For a time its sponsors stood alone. The chief delegate of Great Britain went so far as to declare formally to the U.S. representatives that his delegation would never allow that point to be carried out and that they "would fight us tooth and nail." The Italian delegation was frank enough to announce that its sentiments were in favor of the American proposition, but, owing to the nature of the contracts between the Marconi Company and the Italian Government, it could not support the proposal. The delegation of the United States was determined not to make any concessions preferring to be defeated, if necessary, in order that it might bring its proposal before the Conference and give notice to the world that the U.S. Government stood for the principle that intercommunication must be obligatory between ship and ship.[16]

As the debate continued the United States began to gain support as Germany, France, Austria, Hungary, Belgium, Holland, and Russia shifted their positions. The British delegation then offered to concede insofar as messages relating to saving life and property at sea were concerned. The Germans countered this by proposing that messages related to navigation should be considered in that category. Additionally, they proposed that the Conference should commit itself to an expression of hope that the next conference would adopt the American proposition. The American delegation continued to maintain their steady day-by-day pressure to attain what to them seemed so very vital. Under the influence of this insistence, and following much spirited and somewhat heated debate, the opposition to their proposal began to wither. Finally, in the session of 31 October, they were rewarded with the great satisfaction of seeing their proposal, in the form of a supplementary agreement providing that every ship station referred to in the first article of the International Radio Telegraphic Convention "shall be bound to intercommunicate with every other shipboard station, without distinction as to the radiotelegraphic system adopted respectively by these stations," carried by a majority vote of the Conference. With the exception of Mexico, the delegations of all the countries which had previously indicated that they desired no exclusion of compulsory communications by their shore radio stations, signed this agreement. In addition to these, the delegations of Denmark, Spain, France, and Turkey also voted for this measure.[17]

Having gone down in defeat as antagonists of article 3, the British delegation had submitted a proposal to the Committee on Regulations which provided that a surtax might be charged when stations employing one system were forced to receive and transmit messages emanating from a rival system. This proposal was entirely out of accord with the broad and liberal spirit which animated the Conference. Although the

[14] Ibid.
[15] Ibid.
[16] Ibid.
[17] Ibid.

British proposal was presented most plausibly and with marked ability, it was plainly intended to make parties to the Conference generally assist in the payment of such royalties or indemnities as might be due the Marconi Co. by Great Britain. The proposition was being debated at the same time as the compulsory ship-to-ship one, but came to a final vote first. The American delegation fought it vigorously and exposed its character so effectively that the decision went overwhelmingly against the British position. As a result of this defeat the British delegation lost much of its following, and this was instrumental in the American victory on the ship-to-ship proposal.[18]

The success of the American delegation was due to the unusual position it occupied at the Conference. This was the result of the United States being neither involved in the ownership nor the operation of telegraph or other systems of communication nor restricted by engagements with private interests which were conducting business ventures of that nature. Its delegates at the Conference were able to direct their energies, singly and solely, to the primary purposes of the Conference in their broadest interpretation; the adoption of provisions calculated to promote a wider use of international radio under proper control, to bring its benefits home to the greatest number of people, to stimulate further invention, and to encourage progress and development in the application of the results already achieved.[19] Absolute freedom of action placed them in a very strong position, as was amply demonstrated by records of the proceedings, and even more so by the remark of the Emperor of Germany. After the final adjournment, he told the American delegation that the United States had saved the Conference from failure, and he expressed, with marked emphasis, his appreciation of their efforts.[20]

All the documents embodying the decisions of the Conference were signed on 3 November, exactly 1 month from the date it convened.[21]

The agreements had an effective date of 1 July 1908, or upon ratification if of a later date, and were to be tentative in character and were to remain in force for an indefinite time. It was believed that various modification and extensions would be suggested by experience before the next conference which was scheduled for 1911. The main provisions of these agreements were:

The requirement for compulsory communications between all coast and ship stations. Great Britain reserved the right to organize a separate system of shore stations in fulfilling this requirement;

All radio stations must accept, with priority handling, calls of distress from ships, and must answer these calls with priority dispatch;

The establishment of an International Bureau at Berne, Switzerland, for the housing and distribution of information regarding the several systems in use and the wireless stations in each country; and,

The tariffs to be charged for international radio communications.

The Italian delegation made reservation of its Government's ratification until such date as it could reach agreement with the Marconi interests.[22]

Summing up the work of the Conference and the four documents which emanated from its efforts, it is observed that it not only achieved notable results concerning vital matters but it also explored the entire subject in detail as indicated by the total of 100 proposals which were introduced and discussed. A large number of technical administrative regulations, as well as such problems of regulations of interference by one station with the workings of another; the imperative priority of distress calls over all other communications, with the extension of this rule to all commercial naval and military stations; the steps taken toward the settlement of the delicate question

[18] Ibid.

[19] Ibid.

[20] Ibid.

[21] Excerpts from these documents, the "International Radio Convention," the "Additional Engagement," the Final Protocol, and the Service Regulations are reproduced in app. F.

[22] "The Convention Adopted by the Second International Radio Telegraphic Conference," Berlin, Germany, 1906 (app. F).

of colonial representation in a future conference; and the scheme of arbitration laid down in the event of disagreement between parties to the Convention were worked out at the expense of much labor on the parts of the delegates.

Several months later, Manney, while being interviewed in London on various naval subjects, voiced his opinion concerning U.S. naval radio:

> I have been grateful to learn as a result of attending the Wireless Telegraphy Conference in Berlin that we also lead in this science.[23]

THE STRUGGLE FOR RATIFICATION OF THE BERLIN CONVENTION

President Roosevelt transmitted the proposed treaty to the Senate with the recommendation that it be ratified. Hearings on this began before the Committee on Foreign Relations on 15 January 1908. The chairman, Senator Frye, had been briefed previously by Admiral Manney. In this briefing the events of the Conference were related in detail, especially the opposition which had been overcome by the United States delegates in compelling recognition of the principles and purposes of the United States, all of which were considered unselfish and designed to create a wider and more systematic use of radio in the best interests of the world at large.[24] Manney stated that he considered it vital that Federal legislation be enacted to control the conflicting interests, and that the United States become a party to the treaty since international incidents brought about by radio transmissions from our mainland and our possessions could easily arise. Incidents of noncooperation were cited as necessitating international regulation.[25]

Ex-Attorney General of the United States, the Honorable John W. Griggs, then president of the Marconi Wireless Telegraph Co. of America, appeared before the Committee and led the fight for the Marconi interests. He submitted a "memorandum of objections" which contained many pages of arguments opposing ratification, because such action, it maintained, would most seriously and injuriously affect the business and profits of the Marconi interests and practically destroy the advantages which the inventor and his assignees expected to receive and were entitled to obtain from the priority of their inventions and from the establishment of their system.[26]

The salient points of this memorandum and his testimony were:

> The convention is repugnant to the Constitution of the United States.
>
> Radio is a recent discovery and assent to the convention would be premature.
>
> The convention commits this Government to the policy of government operation of wireless telegraphy for commercial purposes.
>
> The arrangement proposed represents an enforced partnership to which the Marconi companies contribute everything and the German manufacturers of radio apparatus nothing, neither invention, nor capital, nor skillful enterprise.
>
> The rates fixed by the regulations are not remunerative.
>
> Satisfactory working involves not only uniform apparatus but uniform methods.

The authors of the memorandum were vehement in their objections stating:

> We object, therefore, to the mandatory provisions of

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[23] Electrical World (McGraw-Hill, New York), 27 Apr. 1907, p. 828.

[24] "Memorandum Concerning the International Wireless Telegraph Convention, Concluded at Berlin, Nov. 3, 1906," placed before the Committee on Foreign Relations of the Senate of the United States, p. 4, files, Bureau of Equipment, National Archives, Washington, D.C.

[25] Statement of Rear Adm. H. N. Manney, USN, (retired), dated 25 Nov. 1906, in reference to executive A, 60th Cong., "An International Wireless Telegraph Convention With Service Regulations Annexed Thereto, a Supplemental Agreement, and a Final Protocol. All signed at Berlin on November Third 1906 by the Delegates of the United States and Those of Several Other Powers," p. 13, files, Bureau of Equipment, National Archives, Washington, D.C.

[26] Senate committee hearings on "International Wireless Telegraph" before Committee on Foreign Relations, US Senate, during the First sess., 60th Cong.—"Senate Committee Hearings, 1906–12," vol. 10.

articles 3 and 14 of this Convention, because, in effect, it is taking the property of the Marconi Company and subjecting it to the use and service of others against the will of the owners, and to their injury.

We object, further because the Convention provides no adequate means of compensation for such service.

We object because the Convention, if adopted by the United States, will impair the value of the patents issued to Marconi and thus violate the national faith.

It stated that a committee of the British Parliament, which had this convention under consideration, had stated that if British ratification caused damage to the Marconi interests those interests should be fully compensated for their losses. Insistent the American Marconi interests should receive the same treatment, they stated:

We respectfully insist that if this treaty is ratified by the United States the owners of the Marconi patents are likewise entitled to recompense for injury and loss.[27]

The next witness appearing before the Chairman was Mr. Cloyd Marshall, representing the United Wireless Company.[28] He presented a brief, signed by Christopher Columbus Wilson, notorious President of the company, in support of ratification. This was mostly a denunciation of the Marconi interests, but the final three paragraphs dealt with the treaty and are quoted:

We are firmly of the belief that the ratification of the Treaty would be advantageous not only to the government, but also to the wireless telegraph companies, although we think that great care should be exercised in embodying service regulations into laws, so that the development of the industry will not be hindered by impracticable or unscientific regulations. The powers of licensing and witholding licenses to stations or operators would make it possible for this board or a government department to destroy the business of an established company. But we think this is no more than is the case of the Interstate Commerce Commission, which has very great power over the interstate railroads. As we understand it, it is the policy of the Government to foster the development of wireless invention and its use, and to duly encourage such companies as are striving to give a wireless-telegraph service to the merchant marine and also for the handling of the overland business.

The advantages of compulsory intercommunication have been ably set forth by the memoranda submitted by the officers of the War and Navy Departments, and we believe that as a matter of safety on the high seas there is nothing to equal wireless telegraphy, which enables the ship to keep in communication with shore and call for assistance or orders when in distress.

"We therefore recommend and believe that there should be incorporated in the Service Regulations the provision that all vessels carrying the American flag should be required to be equipped with wireless stations within a reasonable period of time. This would work no hardship upon the shipping interests, as the expense of a wireless-telegraph installation is moderate in comparison with the expenditures for other safety devices on board passenger steamers."[29]

Mr. James F. Hayden, representing the National Electric Signaling Co., submitted a brief which, in substance, was similar to the one submitted by the Marconi interests. When questioned by the Chairman, he stated that in his opinion the Marconi Co. was standing on its strict legal rights in refusing to communicate with a company which it considered to be infringing its patents. Analysis of the objections of the National Electric Signaling Co. reveals that the principal reason for their opposition was based on presumed financial injury resulting from impairment in the value of its patents.

Mr. F. W. H. Clay, also an attorney for the National Electric Signaling Co., in a letter to Senator McCreary, a member of the Committee, stated in substance that the real effect of the proposed regulations was to restrict operations to the capabilities of the poorest apparatus and to chain our inventive genius to the inferior genius of many other nations. He stated that in the popular mind a great deal of mystery existed concerning radio, as well as an erroneous assumption that it was already a fully

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[27] Ibid.

[28] The United Wireless Co. was the successor to the American De Forest Wireless Telegraph Co. C. C. Wilson had, by this time, ousted A. White from the control of this company.

[29] Hearings on "International Wireless Telegraph" before Committee on Foreign Relations, US Senate, during the 1st sess., 60th Cong.—"Senate Committee Hearings, 1906–12," vol. 10.

developed art, fixed in status, and viewed in that manner by signers of the convention. He concluded with the following paragraph:

> It is axiomatic that laws not needed are detrimental. This is especially so in dealing with an art now new but liable to expand and develop beyond the dreams of the poet. It might be well by international law to force ships and shore stations to abstain from interfering with each other, leaving it to them to devise means for so doing, and to transmit messages from ships at sea at recognized rates. But I submit that if this is not as far as the law ought to go, and if more definite regulations are to be adopted, such adoption ought to be delayed until a full conference is had with experts skilled in this art, and until a careful consideration of the danger to restriction of invention and property rights can be had after a fuller understanding of the present condition of this art in our own country. The Constitution has proven itself capable of adoption to new conditions, because its provisions are general. This Convention is already out of date before adoption, because its provisions are specific, and specific to a state of the art which American inventors have already left behind.[30]

Mr. Walter M. Massie, President and General Manager of the Massie Wireless Telegraph Co., a small concern with equipment installed in passenger vessels plying between the ports of New York, Providence, and Boston, wrote, stating:

> The principal question is that of "interference." Stations at several miles distance cause serious trouble in this respect, but wireless inventors are endeavoring to overcome the obstacle and believe it will be accomplished before long. The wireless treaty is dealing with the situation as it now is, and should it be ratified there will be no object for inventors to perfect this or other features of the system.
>
> Another important question is the requirement of all stations to exchange messages regardless of the system used. This point should be settled by the steamship managers themeslves, and we are surprised they have not, before this, refused to install a system that would not communicate with other vessels irrespective of system used. It is for their benefit to know, for instance, the location of a derelict in their path of navigation; refusing such news is not only endangering their ships but the many lives they carry.[31]

Brig. Gen. James Allen, USA, Chief Signal Officer of the Army; Lt. Comdr. Cleland Davis, USN, who had relieved Robison as Head of the Radio Division; Mr. Eugene T. Chamberland, Commissioner of Navigation; and Mr. Charles Earl, of the Department of Commerce and Labor, represented the Executive Branch of our Government at these hearings. They jointly submitted a very lengthy argument on behalf of the treaty and advocated that it be ratified without delay. Prominent among the many salient points of their argument was their conviction that the Convention, in its most important features, was peculiarly the work of the U.S. delegation. Not only was it an important and timely measure, in the line of progress in commerce and science and in the interest of the better safeguarding of life and property, but it was also an international accomplishment acceptable from our national point of view. Both in its principles and provisions, the treaty met with the strong support and approval of every branch of the Government having concern in the matter. They felt that ratification of the Convention by the United States would carry great weight with other powers who were considering it. Contrariwise, the influence of the United States, acquired in a marked degree by its representatives at the Conference, would likely be lost by delay.[32]

In rebuttal of the suggested postponement of action until such time as the business of radio had developed to its broadest scientific possibilities, they considered this would prolong the period of uncertainty without providing any solutions upon which the future could be determined, since it was impossible to predict when its scientific aspects would undergo such important changes as would necessitate modification of the Convention's regulations. The Convention, as drafted, provided means of renunciation which required only a notice of 1 year for such renunciation to become effective. At any time the Government found the agreement detri-

[30] Ibid.

[31] Ibid.

[32] Ibid.

mental to the Nation or to the disadvantage of its people or industries, this could be invoked. Considering that the enactment of Federal legislation for the control and regulation of radio was necessary, the ratification of the Convention would provide a basis, international in scope, upon which to frame such legislation.[33]

Much of the argument of these officers was devoted to the desirability of compulsory intercommunication, claiming that the enforcement of this between ship and shore and between ships possessed a strong claim to recognition, since the principle involved had received the support of the representatives of 27 of the chief nations of the world. They noted that even the spokesmen of those nations which could not concur, because of contractual agreements, frankly acknowledged the fairness of compulsory intercommunications. They stressed that "compulsory intercommunication, internationally obligatory," provided the only positive method of assuring vessels in distress the benefits of radio and, therefore, should be demanded in the interests of humanity. The opening of the field to any and all users, and thus fostering competition by promoting its use and increasing the demand for it, was clearly calculated to stimulate invention and encourage development and improvement. In the case where different systems were involved and the choice between compulsory intercommunication or refusal to communicate presented itself, the former practice would obviously bring benefits to the greater number. Such a practice, permitting stations equipped with any form of existing equipment to communicate freely with the greatest number of other stations, would facilitate and extend intercourse, and thus manifestly be of immense importance to commerce and navigation. Contrariwise, arbitrary restriction upon such a practice, enforced in the interests of a particular system, would be to their detriment. By encouraging the application and promoting the development of radio, and thus tending to place merchant vessels in a state of organization, legislation on compulsory intercommunication would be important from a naval point of view, since such merchant ships, properly outfitted, could be made use of by the Navy as a source of information and for other purposes.[34]

The supporters of the treaty were of the opinion that the only alternative to compulsory intercommunication was the existing situation in which the firms or individuals engaged in the operation of radio were free to refuse any message tendered by another system, regardless of the urgency of the message. They were prepared to cite instances to demonstrate that such a situation was intolerable. Under the terms of the agreement it would be impossible to restrict the application of the principle of compulsory intercommunication to calls of distress, and to so limit the principle by the legislation of a single government would prove ineffective. Even if practicable, to so restrict the principle by a new international agreement would be insufficient, as the operator of the receiving station could still be the judge of the urgency of the communication. Any such restriction upon the principle would fail to consider the rights of the general public "to free and untrammeled intercourse through the use of this instrumentality." [35]

Concerning the desirability of preventing or minimizing interference, they observed that so far as was known there were no laws, either State or national, for the regulation of radio operations. Such being the existing situation, anyone was at liberty to use the ether when and how it pleased his fancy, utterly unmindful of the effects produced upon other stations, be they military, naval, commercial, or experimental. Repeated instances of interference and confusion often rendered communication uncertain or impossible.[36]

[33] Ibid.

[34] Ibid.

[35] Ibid.

[36] Ibid.

In rebuttal of the statement by the Marconi interests that "the rates fixed by the regulations . . . are not remunerative," they pointed out that "it is a principle universally recognized by those who are engaged in what is termed 'a public employment or service' that they must carry on their business upon reasonable terms. The business of conducting a wireless telegraph service is an employment of this character. It is only to be expected, therefore, that in framing regulations for the Government of this business of international obligation so fundamental a proposition as this should be taken note of and provided for." [37] They further stated that the only proof given in support of this contention was that the rates fixed were less than those then being charged by the Marconi Co., under which that firm maintained it had not been able to pay its operating expenses and earn a return on the capital invested and the value of its patents. This, it was felt, was far from proving that the rates fixed were not reasonable, which was the only question considered pertinent. It was surmised that the rates being charged by the Marconi Co. could be, and probably were, too high, but before it could be stated that the rates fixed would not yield a fair return various matters would have to be investigated, among others "the relation between capitalization and actual investment, the cost of operation, maintenance, and depreciation, as well as the probability of increased business as a result of the encouragement given to wireless communication by reason of the liberal policy of the agreement." [38] In support of their opinions they advised that Mr. H. Babington Smith, one of the delegates of Great Britain, had stated to the Select Committee of the British House of Commons, with reference to the rates fixed: "These limits are considered somewhat high for ordinary stations, but each government is at liberty to fix lower limits for its own stations if it thinks it desirable."

As to the reasonableness of these rates fixed they stated:

"That it was fixed by representatives of governments who are themselves operating wireless telegraph systems and who therefore may safely be presumed to know from experience what would be a proper charge.

The Convention itself provides that notwithstanding the maximum each government is nevertheless at liberty to authorize higher rates in the case of stations whose ranges exceed 800 kilometers or whose work is exceptionally difficult.

Notwithstanding the fact that the Marconi Company was represented both at the international conference and at the hearings before the Select Committee of the House of Commons, at neither of these places does it appear that any objection was made to the charges fixes." [39]

In concluding their argument the Government representatives stated:

". . . . . that the agreement reached was designed to accomplish, within practical limits three great results—first, the effective establishment of general intercommunication between all systems and stations, without discrimination; second, the effective elimination of interference, intentional or unintentional, between stations; third, the opening of the service of wireless telegraphy to the public upon reasonable terms.

"The ratification of the agreement, it is believed, depends primarily upon whether in the judgment of the Senate, these three requirements are severally desirable." [40]

Mr. John I. Waterbury, one of the United States plenipotentiaries to the Conference, did not appear before the Senate Committee but he submitted a statement in support of its ratification. Salient portions of this stressed the inevitability of international action, regardless of whatever incidents may have precipitated action as early as 1903. The rapid expansion and use of apparatus for employing the ether as a public highway for the transmission of

[37] Ibid.

[38] "Memorandum Concerning The International Wireless Telegraph Convention, Concluded at Berlin, Nov. 3, 1906," before the Committee on Foreign Relations of the Senate of the United States, p. 12.

[39] Senate Committee hearings before Committee on Foreign Relations on "International Wireless Telegraph," 1st sess., 60th Cong., 1906–1912. vol. 10.

[40] "Memorandum Concerning the International Wireless Telegraph Convention, Concluded at Berlin, Nov. 3, 1906," before the Committee on Foreign Relations of the Senate of the United States.

radio communications resulted in confusion which threatened "serious curtailment of the vast benefits to humanity which the discovery had promised." With radio installations anywhere near the border he clearly saw that among the possibilities were international complications, likely to be unpleasant and vexatious, if not worse. Aside from such contingent problems, there were existent wrongs directly emanating from the absence of proper regulation—wrongs that were becoming a form of anarchy repugnant to progress and "detrimental in high degree to public welfare in the broadest application of the term." He cited the friction between conflicting interests and the deliberate obstructions purposely placed in the way of attempts to avert danger to life and property at sea.[41]

As he saw it, in the final analysis, all the discord, all the curtailing of the benefits to mankind in general from the new medium, all the savage obstructions to attempts to protect life and property on the high seas, all the chaos and lawlessness into which the practical use of radio was rapidly drifting, turned upon the two points on which there was nonagreement—"obligatory communication between stations regardless of system, and noninterference between stations." [42]

THE SHELVING OF THE TREATY

The proponents of ratification might have continued on and on providing excellent reasons for Senate action, but these would have had little avail against the determined opposition of the commercial interests and their thousands of stockholders. The Senate committee's action on the convention was summed up in a news item in the 1 February 1908 issue of the *Electrical World*:

"It is stated from Washington that the Republican members of the Senate have reached a virtual agreement to take no action relative to the Wireless Telegraphy Treaty which has been pending before the Committee on Foreign Relations since almost the first day of the session. This conclusion is in spite of the fact that a dozen or more great powers have already approved the treaty and are now waiting for the cooperation of the United States. It is proposed to let the wireless Treaty remain in the committee indefinitely while the Navy Department watches the behavior of the wireless companies. If they refuse to transmit distress signals or show reasonable cooperation the treaty will be taken from its pigeon hole and ratified. The passage of the treaty would place all companies under international supervision.[43]

While in retrospect it may be difficult to understand what appears to have been procrastination on the part of the Senate, that body was simply reflecting the prevailing business sentiment of the time. President Roosevelt had already irritated "big business" by antitrust actions and the Republican Party, in that election year, was little intent upon causing further antagonism. Its failure to foresee that its inertia was aiding the British-dominated Marconi Wireless Telegraph Co. of America was unfortunate, but in those early days of the new medium, when comparatively little was known about it, the committee's cautious approach to the problem should not be considered unusual. With the Marconi and National Electric Signaling interests arrayed against ratification, and with the strong cases presented by their leader, Mr. John W. Griggs, the result was as might be expected.

Upon being informed of the intention of the Senate committee, the Secretary of the Navy addressed a letter to both branches of Congress, via the President, in which he recommended:

That such legislation be enacted as will insure freedom of official messages from interference. To accomplish this the law should make it a punishable offense—

(*a*) To originate or transmit a false message purporting to be official;

(*b*) To break in and interfere with any wireless

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[41] Memorandum dated 21 Jan. 1908 concerning International Wireless Telegraphy Convention concluded at Berlin, Nov. 3, 1906, by Mr. John I. Waterbury. Senate committee hearings before Committee on Foreign Relations, 1st sess., 60th Cong.

[42] Ibid.

[43] Electrical World (McGraw-Hill Publishing Co., New York), 1 Feb. 1908.

station while it is transmitting an official message;

(c) To refuse to cease or fail to cease sending a private wireless message when called upon to do so by an operator having an official message to be sent.

It will be noted that the enactment of law of the nature proposed would never seriously interfere with the legitimate working of commercial wireless installation. The restrictions suggested are intended to apply particularly to times of peace. During war, it is contemplated that much more extensive prohibitions would be exercised to be put into effect in the absence of legislation by executive proclamation as a belligerent right.

In transmitting this to the Senate and the House of Representatives, on 13 February 1903, President Roosevelt added:

I cordially indorse all that is above stated and recommend the passage of such legislation as will accomplish the desired end.

THE STRUGGLE FOR EFFECTIVE CONTROL CONTINUES

The request of the Secretary of the Navy and its endorsement by President Roosevelt led to the immediate introduction of three separate measures for the control of radio; one in the Senate by Senator Hale and two in the House, one by Mr. Shephard and the other by Mr. Peters.

The Hale bill, with a proposed effective date of 1 July 1908, contained clauses requiring all radio stations engaged in foreign or interstate communication to be federally licensed at a fee of $100 per annum for fixed stations and $5 per annum for ship stations; compulsory relay of messages regardless of ownership or equipment; and the answering of calls of any other licensed person or corporation by every person or corporation holding a Government license. It further provided that the President could abolish licenses in time of war; prescribed heavy fines or confiscation for violation of the above; and prescribed severe penalties for interference with messages sent or intended for Government offcials, or for the malicious use or operations of wireless instruments under license by the Government.[44]

In commenting on the bill introduced by Senator Hale, the Electrical World in an editorial in its issue of 21 March 1908 stated:

The several bills now before Congress for the regulation of wireless telegraphy are an indication of a condition which undoubtedly calls for some action eventually on the part of the Federal authority. None of the present bills, however, appears to represent a sufficiently mature or broad consideration of the subject to which they relate, and the Hale Senate bill is no less than pernicious in some of its provisions. With the ether as a common medium of transmission, which medium can be preempted at pleasure by a youth for amateur play, or at any moment rendered unavailable for serious purposes by malicious disturbances from stations of competing wireless companies, the need of some regulation of its use cannot be gainsaid. The Hale bill, however, would in effect make the ether an instrument of warfare and in time of peace an appendage of the military establishment. It was in this spirit that wireless regulation was discussed at the Berlin conference of 1906, and the international agreement there drafted appears to have very properly been pigeon holed by the committee of the Senate before which it came for consideration in the form of a treaty. But we now have in the Hale bill an attempt to enact by indirection some of the most criticised features of the Berlin agreement, which are rendered more objectionable by limitations in the sole interest of our military establishment. This attitude recalls the recommendation of a naval authority several years ago, that the coal fields of Eastern Pennsylvania—the source of supply of some millions of people—should be pre-empted for war purposes.[45]

The editor went on to note that any regulation of radio should be based on recognition of the fact that it was a new art, still in its infancy, and for proper development freedom from every unnecessary restraint was desirable. Agreeing that government had a prescriptive right to an art given the world by a long line of inventors and scientists, such was hardly an inference that such a right could not be exercised "with due regard to the use of the same art for nongovernmental purposes." Should there arise in time of peace an occasion of

[44] Electrical World, vol. LI, No. 12, 21 Mar., 1908, pp. 589–590. "Wireless Companies Oppose Hale Bill" (McGraw-Hill Publishing Co., Inc., New York).

[45] Ibid.

sufficient importance to require temporary preemption of the ether by the Federal Government, inconveniences occasioned thereby to private and commercial interests could be endured with some equanimity. However, assurances should be provided that interruptions of such a nature would be incident to matters of real significance, and that private interests would not be sacrificed to routine communications which could just as well be transmitted by other means, or by trivial messages among officials. To avert a gross abuse of the radio privilege by inconsiderate or overofficious persons, there should be a definition of the nature of Government communication by radio, as well as a requirement that a copy of every communication be filed for critical examination of its real importance. Thus, any peacetime preemption of the ether by the Government should only be for emergency purposes, and officials should be held strictly responsible for the proper exercise of such a privilege. In common with all the peaceful arts of civilization, radio would, in time of war, be relinquished to military usage. "But as a recompense," he observed, "it should not be held in abeyance in time of peace in accordance with what appears to be a policy for the exaltation of the military over the other classes of American people, which classes would be the ones to give their resources and offer up their lives in national defense, and not even balk if the nations should become committed through vainglorious bravado to a war of foreign aggression. While he felt that none would deny the need of some radio regulation, its character should be such as to be subject to careful consideration in the interests of the medium and the people as a whole. He suggested the creation of a commission by Congress to investigate the matter and make recommendations, but cautioned that membership should be so constituted so that neither military nor bureaucratic elements would dominate it. It was hoped that no hasty congressional action would be taken before the subject of regulation in the United States had been exposed to "much broader and wider consideration than is evidenced by the bills thus far offered in Washington." [46]

Another item in the same issue quoted the views of the Marconi and United companies, which characterized the Hale bill, as introduced in the U.S. Senate on 6 March 1908, as the third in a series of efforts to circumvent a pledge of the leaders of the Senate, who, it had been stated, had assented to shelving action on the ratification sought by the American delegation to the International Radio Telegraphic Convention held in Berlin, November 1906, it being known to them that both the United Wireless Telegraph Co. and the Marconi interests were bitterly opposed to the Hale measure in the form presented.[47]

Also brought out in the same article was that there were two other bills before the House, those of Messrs. Shephard and Peters, which, if adopted, would have the effect of making radio a Government monopoly.[48]

Mr. S. S. Bogart, vice president of the United Wireless Telegraph Co., voiced objection to a section of the Peters bill which specifically provided that the use of 700- and 800-kc. frequencies were prohibited except for official stations, concerning which he said, "The passage of this bill would throw out all long-distance commercial stations and practically make wireless telegraphy inoperative."

One part of the Shephard measure provided that the originating or transmitting of false messages purporting to be official be a penal offense, to which the companies gave their approval, but they strenuously opposed its sections 5 and 6, involving the breaking in or interfering with radio stations transmitting official messages, which was not well understood by them. They felt it would be extremely difficult, if not impossible, for the Federal or for State governments to pass laws preventing interference. Such attempted legislation on the part of those lacking adequate knowledge

[46] Ibid.
[47] Ibid.
[48] Ibid.

of a subject with which they were incompetent to deal was, to them, entirely unnecessary.

Vice President Bottomley, of the Marconi Co., expressed himself to the effect that the above bills represented an attempt of the Government to create a monopoly and that the "Government was controverting its past policy of keeping clear of the field of commercial enterprise."

Thus while the Government departments continued in their efforts to effect Federal regulation, and had the support of President Roosevelt, the commercial interests, with their large number of stockholders, remained sufficiently powerful to forestall legislation. The Congress adjourned without voting on any of the three bills.

CHAPTER XI

The Early Radio Industry and the United States Navy

THE CONDITION OF THE RADIO INDUSTRY

At the time the Senate Committee on Foreign Relations was considering ratification of the 1906 Berlin Convention, the radio industry in this country was badly in need of investigation.

In the earlier years hundreds of patents had been granted, yet, excepting a few, there was but a modicum of originality in any. This was caused by the fallacious view of the patentees that any improvement in vital or accessory components was fundamental and resultant in distinctly different methods of radio communication. This was intensified by the equally fallacious acceptance of this view by the many national patent offices which failed to realize that in so doing they were essentially allocating the use of something over which they had no control, something that belongs to every living thing, the air. Such a situation could have but one result—the various patent holders of so-called systems considered every other patentee a thief and a scoundrel, and instead of cooperating to provide stamina to the young industry they were stifling its growth by malnutrition. Although infringement suits had been slow to develop and slower yet in adjudication, the judgments rendered were beginning to become effective. The largest company in this country was completely controlled by notorious individuals who were continuing to use it as a medium for the sale of stock the proceeds of which were misdirected to individual usage or for advertising purposes without greatly enhancing the real assets of the company.

In the field of commercial radio operations 188 commercial vessels of U.S. registry were fitted with radio equipment of which only 83 were under American Marconi Co. contract. The largest number of shore stations of any one company was the 39 erected by the American De Forest Wireless Telegraph Co., but the actual reason for these was for stock promotion rather than for communications.

U.S. engineers and scientists were improving appurtenances and auxiliary apparatus and obtaining slightly better ranges in transmission. In 1906 De Forest discovered and applied for a patent on the three-element vacuum tube as a detector. In the same year Gen. H. H. Dunwoody, USA (retired), discovered the rectifying property of carborundum, while Mr. J. G. Pickard disclosed that silicon possessed the same property. Fessenden by this time had been successful in transmitting speech between Brant Rock and Plymouth, Mass., utilizing a small, high-frequency alternator. In 1903 Poulsen developed the arc transmitter to the extent that he was able to transmit for a distance of 150 miles. In 1909 the U.S. rights to the Poulsen transmitter were purchased by Mr. Charles Elwell.

Development in the United States was accomplished without very exact quantitative knowledge of the involved factors.

Frequently, capacity, and inductance were the only ones normally measured. High-frequency currents, above the range of 6-ampere thermal ammeters, were usually measured by the use of shunts of inexactly known resistances, thus providing measurements which were only approximations. The energy losses in equipment were seldom determined. Fessenden had measured the strength of receiver antenna currents by means of the shunted telephone method, but the results were not accepted by other radio engineers and scientists. Most of the commercial radio interests in this country, with the exception of Fessenden, Stone, and a few others, were more interested in establishing communication networks or in financing stock promotion than in providing the necessary funds for research and development of more efficient apparatus.

THE UNITED WIRELESS CO.

In the radio stockbrokerage field, Abraham White, who earlier had so thoroughly eliminated the Gehring interests, now began eying the American Marconi Co. The idea of gaining control of that company looked so big to White that, without consulting its directors, he announced in the newspapers, one Sunday morning in November 1906, the formation of the United Wireless Telegraph Co., organized and capitalized at $20 million for the purpose of uniting the different radio systems, including those of the Marconi and American De Forest companies, as well as for acquiring the latest and most approved inventions employed in the art and for continuing its development and expansion throughout the world on a broad and comprehensive scale.[1]

Included among the directors were White and his former satellites, plus a member of a well-known New York Stock Exchange firm and a prominent banker from Pittsburgh. The last two named remained on the board just 24 hours. From the moment White displayed their names upon his half-page advertising, a "stream of incredulous inquiries poured in on them from their friends," and with as good grace as possible they quickly severed their connections.[2]

Leading Marconi promoters on both sides of the Atlantic made immediate and irate protestations. Marconi cabled from Italy that it "was all Greek to him." Emphatically denying any merger plans of the De Forest and Marconi firms, the President of the Marconi Wireless Telegraph Co., Mr. John W. Griggs, characterized White's "merger" as "antagonistic and repugnant to the Marconi companies." White continued "merging," the denials of the enemy notwithstanding, and succeeded in winning over one Marconi director, who was immediately ousted from that company's board. A notorious firm of Broadway brokers which had been "hawking Marconi shares around the country at fictitious prices" also succumbed to White's wiles.[3]

A sample of the alluring prospects offered is gleaned from the statement below taken from a circular outlining details of the plan for exchanging United Wireless and American De Forest securities:

> For every dollar paid by you for De Forest preferred or common stock there will be issued $1.10 worth of United Wireless Telegraph Company preferred stock, plus 5% thereon for every year the stock has been held by you for over one year. To holders of bonds who desire to exchange them for preferred stock, we will exchange by allowing 20 percent on the par value of the bonds and the holder will be allowed to retain his bonus stock. To the holders of bonus, cut rate, or broker's stock we will exchange at the rate of one share of United for six of American De Forest. This applies either to preferred or common stock purchased prior to January 1, 1907. All stock exchanged must be held in escrow in bank or trust company for two years.[4]

For the first time De Forest realized White's true intentions and strenuously ob-

[1] Electrical World (McGraw-Hill Publishing Co., New York), 24 Nov. 1906, p. 984.

[2] Frank Fayant, "The Wireless Telegraph Bubble," Success magazine, July 1907, p. 482.

[3] Ibid., p. 482.

[4] Electrical World, op. cit.

jected to his actions. This aroused White's ire. He completely ignored De Forest and left him completely out of the new organization. In a letter to Frank Butler, dated 10 October 1906, De Forest explained the existing situation:

> That philanthropist has cut me off entirely. I can't get a dollar from the company nor will he allow me to sell my stock.
>
> . . . It's pretty tough after all I've done to make the enterprise out of which so many were reaping huge commissions a success . . . to get this treatment . . . As soon as your immediate usefulness was ended, it was a case of "to hell with you." I might have foreseen my own treatment from the treatment you received . . . Reformation is an impossibility. There will be no great things in wireless until the present management is out.

For his entire holdings in the American De Forest Wireless Telegraph Co., including all patents excepting those pending on the three-element vacuum tube, De Forest received a paltry $500. His attorney pocketed one-half of that.

White was not successful in his efforts to obtain control of the American Marconi Co., but he did succeed in obtaining control of and absorbing Shoemaker's International Telegraph Construction Co. Shoemaker, for the second time, went to work for White, and his brilliantly started career became hitched to a lodestone.

In the late summer of 1907, "ex-Confederate Army Colonel Christopher Columbus Wilson, stock promoter par excellence, 'Colonel Sellers' incarnate," [5] the erstwhile general western manager of the American De Forest Wireless Telegraph Co., dissatisfied with his share of the spoils, succeeded in ousting White from the presidency and from the board. Wilson continued and expanded the stock-peddling policies of the company and made White look like a rank amateur as he further depreciated the physical assets of the firm. The below-quoted statement of Mr. John Firth provides an idea of the standing of the United Wireless Telegraph Co. in financial circles.

> . . . Just as I was arranging to leave New York for Pittsburgh I received a telephone call from Colonel Wilson, President of the United Wireless, asking for an interview. I informed him I was leaving New York that evening, and would not be able to see him until my return to New York. He asked me what time I was leaving and I said 9:30 p.m. and he asked me to see him at his hotel, Waldorf Astoria, on my way down at 7 o'clock. He then asked me at the interview to become president of the United Wireless Telegraph Company, saying he would retire if I accepted. He also promised me a block of the company's stock. I said I would not under any circumstances accept his proposal as the company had degenerated and was being used to swindle the people by selling them stock that had no value and my final remark was that the company was "conceived in sin and brought forth in iniquity." He was furious.[6]

Unfortunately, no date is connected with the above. Obviously, Wilson, at that time, was looking at the "handwriting on the wall" and was searching for a scapegoat. He did not succeed in accomplishing this, for in 1910 he was adjudged guilty of perpetrating a fraud and, like his erstwhile associate, White, was sentenced to be a Government guest in the Federal Penitentiary, Atlanta, Ga. Following this, the company continued to suffer reverses. The notoriety incident to Wilson's conviction ruined the further sales of stock. In 1912, it was adjudged guilty of infringing Marconi patents and was forced into bankruptcy. Its few remaining assets were purchased by the parent Marconi Co. and given gratuitously to the American Marconi Co.

The officials of the United Co. had so completely degraded it that it ceased to be a factor in the development of the industry. The Navy refused to have any dealings with the White or Wilson interests after the organization of the United Wireless Co.

THE DE FOREST COMPANIES

Discouraged, De Forest, in 1907, joined

[5] Lee De Forest, "Father of Radio" (Willcox & Follet Co., Chicago, 1950), p. 185.

[6] "Radioana," John Firth, "The Story of My Life" (unpublished manuscript n.d.), SRM–5–503, p. 13.

with James Dunlop Smith, once a star stock salesman of White, and Samuel Darby, an honest patent attorney, to form the De Forest Radio Telephone Co. This firm was capitalized at $2 million, and 50 percent of its stock was issued to De Forest in exchange for the US and foreign patents pending on the triode and for the tuned circuit patents of John Stone Stone which were acquired by him at this time, the Stone Co. then being about to dissolve because of lack of revenue.

This new company's basic endeavor was the development of the radiotelephone. In this effort they utilized a version of the Poulsen arc [8] as the transmitter and a combination of crystal and triode detectors in the receiver. The U.S. Navy, searching for a satisfactory radio system for tactical usage, was the company's first customer. In late 1906 they purchased 26 of these equipments for installation in vessels of the "Great White Fleet" prior to their departure on a round-the-world cruise. They were improperly used by naval personnel and for this reason proved a failure.[9] This did not appreciably bolster the company's revenue and they were soon in financial difficulties. Some of De Forest's associates again resorted to sales promotion of the company's stock, but by this time the public had become somewhat wary of the rosy future pictured by the brochures of the day. Unsuccessful in raising sufficient funds the company was forced into bankruptcy in 1911 after the failure of an attempt to merge it into a $10 million North American Wireless Corp. All that was salvaged from this venture was a subsidiary, the Radio Telephone Co. which had been established at the same time as the parent company. De Forest was not to escape the responsibility for the misdeeds of his associates. The same Government crusade against radio stock promoters which resulted in the convictions of White and Wilson ensnared De Forest and two of his sales-promotion force. Aided by his classmates at Yale he was ably defended and was exonerated on the grounds that he had not been aware of the unlawful practices used by his company. The two associates were given penitentiary terms. The Government's primary accusation was that the defendants were selling stock "in a company incorporated for $2 million whose only assets were De Forest's patents chiefly directed to a strange device like an incandescent lamp which he called an audion and which device had proven worthless." [10]

Following the failure of his company, De Forest entered the employ of the Federal Telegraph Co. of California. There, assisted by Messrs. Herbert Van Etten and Charles Logwood, he worked "on problems of high-speed telegraphy, static reduction, and long-range transmission." [11] In 1912 he conducted new experiments with his triode and succeeded in obtaining increased amplification by connecting them in cascade. This proved effective as a telephone repeater and in the spring of 1913 the American Telephone & Telegraph Co. purchased the triode rights for this purpose for $50,000. Following this, De Forest is credited with the discovery of the oscillating property of the triode.[12]

The Federal Telegraph Co., American sponsor of the Poulsen continuous-wave arc transmitter, was utilizing a "tikker" receiver for the reception of this type of emission. De Forest developed his "ultra-audion" for use in heterodyne reception to replace the Federal "tikkers." Later the Navy purchased a large quantity of "ultra-

[8] In 1900, William Duddell discovered that an electric arc would, under certain conditions, generate high-frequency energy. Three years later, Valdernar Poulsen applied this principle to a radio transmitter and produced continuous oscillation at 100 kc.

[9] Infra, ch. XIII.

[10] Gleason Archer, 'History of Radio to 1926" (American Historical Co., New York, 1938), p. 110.

[11] W. Rupert Maclaurin, "Invention and Innovation in the Radio Industry" (the Macmillan Co., New York, 1949), p. 77.

[12] Langmuir, Meissner, and Armstrong also claimed priority in this discovery. De Forest was the winner in a later four-party interference suit.

audions," but their construction was of such poor quality that it was necessary for its radio test shop to redesign and reconstruct them.[13]

About this time De Forest claimed the development of the feedback circuit which could be used either to increase the sensitivity of the audion as a detector or to generate oscillations. This came into conflict with a claim of Mr. Edwin Armstrong, who had delivered a paper describing a "regenerative circuit" in early 1913.[14]

In 1913 De Forest used the $50,000 he obtained from the sale of the telephone repeater rights to the triode and reorganized the Radio Telephone Co., changing its name to the Radio Telephone & Telegraph Co., of whose stock he owned 80 percent. The following year he sold further triode rights to the telephone company for $90,000 and began the manufacture of tubes under the limited rights he had retained.[15] This company managed to stave off bankruptcy for the next decade and did some business with the U.S. Navy but was never looked upon by it with exceeding favor.[16]

[13] Maclaurin, op. cit., p. 77-78. "Radioana" (Massachusetts Institute of Technology, Cambridge, Mass.), G. H. Clark, "Radio in War and Peace," unpublished manuscript, n.d., p. 372.

[14] Armstrong won the original interference suit. In 1928 the U.S. Supreme Court reversed the decisions of lower courts and awarded priority to De Forest. This was reaffirmed by the same court in 1934. Despite this, the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts awarded the Franklin Medal to Armstrong in 1941, stating these decisions were made "much to the astonishment of radio engineers." This statement is supported by the action of the Institute of Radio Engineers which, in 1918, presented Armstrong with it first Medal of Honor award for his work in developing the feedback circuit. When the Supreme Court reaffirmed its decisions in 1934 Armstrong returned this medal, which was promptly given back to him indicating their conviction of his prior claim. (Committee on Science and the Arts, Rep. No. 3087, 8 June 1941, pp. 3–4).

[15] This was not a remunerative business because De Forest tubes lacked uniformity and quality.

[16] Infra, pp. 2M.

THE NATIONAL ELECTRIC SIGNALING COMPANY AND THE SYNCHRONOUS ROTARY SPARK GAP TRANSMITTER

Reginald Fessenden, the hot-tempered, stubborn, self-opinionated, and intolerant scientific director of the National Electric Signaling Co., was long obsessed by the conviction that long-distance radiotelegraphy and telephony could be best accomplished by the transmission and reception of continuous waves.[17]

In 1903 he had interested two Pittsburgh bankers, Walker and Givens, in supporting his research with the idea of developing a radio communication system which could be sold in its entirety.[18] The National Electric Signaling Co. was organized for this purpose. It was not engaged in stock promotion and in fact both Walker and Givens were unalterably opposed to the sale of the company's stock to the public.[19]

During the last decade of the 19th century Nikola Tesla had pioneered the use of the alternator but had not been successful in its use as a transmitter of radio waves. Fessenden adopted this means and had several built to his specifications. None of these proved sufficiently powerful because of his adamant refusal to accept the advice of Dr. E. F. W. Alexanderson, of the General Electric Co., to use an iron core.[20]

Parallel with his endeavor to develop the alternator, Fessenden worked on a synchronous rotary quenched spark transmitter which reduced the damping coefficient to a point where the emission had somewhat the characteristics of undamped waves. He was successful in developing such a transmitter which had some capability of transatlantic radiotelegraphic transmission. It was not sufficiently superior to Marconi equipment to permit further expenditures of funds following the loss of the company's

[17] Maclaurin, op. cit., pp. 59–63; infra, ch. IV.

[18] Supra, ch. IV.

[19] Helen M. Fessenden, "Fessenden—Builder of Tomorrows" (Coward-McCann, New York, 1940), pp. 124–125.

[20] Maclaurin, op. cit., pp. 59–63.

towers at Machrihanish, Scotland, in 1907.[21]

In his search for a receiver for speech transmissions Fessenden developed and patented an electrolytic detector in 1903. This device had the same failing as the coherer in that a cyclic operation was necessary to permit a flow of current from a local battery to emulate the actions of the transmission being received. Continuing the search for a more satisfactory system of continuous-wave reception, he developed the heterodyne method of reception. In his early receivers of this type he utilized a small arc generator to provide the local oscillations. The difficulty in controlling the local generator delayed the acceptance of the heterodyne receiver until De Forest developed his "ultraudion" which could be used as a satisfactory generator of local oscillations.[22]

As previously related, Fessenden during the years 1903-7 had almost constantly berated the Navy because of their failure to purchase his apparatus or to pay his company royalties on the equipments then in use.[23] Being aware of their standing with the Navy Department, the National Electric Signaling Co. engaged John Firth, vice president and sales manager of the Wireless Specialty Apparatus Co., to sell the Bureau of Equipment the 100-kw., synchronous rotary spark gap transmitter which Fessenden had developed for transatlantic communications experiments. This was done in the full knowledge that Firth was on excellent terms with the leading personnel in the Radio Division of the Bureau of Equipment and that the Bureau was specifically seeking a means of direct radio communications between Washington and the Canal Zone as well as equipment to provide long-distance radio telegraphy.[24]

Firth, as a salesman of radio apparatus and appurtenances, had no peer in his day. He did not immediately rush to Washington and endeavor to sell the transmitter, but on every one of his periodic visits to the Bureau he would mention that he would like to see a large installation there so that the Navy Department could be in touch with its ships and stations all over the world. After having voiced this idea for almost a year, one day in the late summer of 1908 he was asked by Sweet, the Assistant Head of the Radio Division, "How is your dream getting on?" This was what he had patiently awaited, and he instantly replied:

> It will come true quicker than you think. I am prepared to take your order today for a 100-kw. set embodying the very latest features in wireless and which will connect you at will with every ship in our service.

Sweet was impressed with the old gentleman's sincerity, and took him to see his superior, who directed him to investigate and contract with Firth, provided the equipment would be guaranteed to meet the specified requirements.[25] Although his connection with the National Electric Signaling Co. may have been suspected, since his own firm did not manufacture transmitters, he did not reveal it until after the decision was made. Regardless of Firth's offer, specifications had to be drawn up and bids requested on the equipment from all possible suppliers. This was done and, additionally, two ship installations were included.

The January 1909 issue of the Electrical World contains a rather caustic news item concerning these, which is quoted in its entirety:

> On Jan. 5 proposals for furnishing long-distance wireless plants for the Navy will be opened, consisting of a sending station at Washington, having a range of 3000 miles, and two equipments for vessels having a receiving range of 3000 miles and a transmitting range of 1000 miles. The circular for prospective bidders is a formidable document which, if taken too seriously, might well deter any manufacturer from submitting a proposal.

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21 Ibid., p. 64.

22 Ibid., p. 61.

23 Supra, chs. VII and VIII.

24 "Radioana," op. cit. (John Firth, "The Story of My Life").

25 "Radioana," op. cit. (G. H. Clark, "Radio in War and Peace," p. 61).

Aside from forms, there are 33 paragraphs, of which 31 consist mainly of conditions to secure the government from any possible loss, or exercise of any generosity toward a manufacturer who might, in his zeal to meet the need by the government for such a plant, too lightly pass over the difficulties incident to its design and construction—these precautions recalling the interesting game of "Heads I win, tails you lose." Apparently exhausted in the work of preparing these safeguards, the writer of the document confines to two paragraphs of the specifications to guide the successful bidder, as follows:

"The station to be capable of transmitting messages at all times and at all seasons to a radius of 3,000 miles in any navigable direction from Washington, D.C. Such messages must not be interrupted by atmospheric disturbances or intentional or unintentional interference by neighboring stations. The station to be capable of transmitting and receiving messages with entire secrecy. The contractor must supply the necessary concrete buildings, with living accommodations for four operators, towers, ground connections, wiring and apparatus complete. Such to be erected at or near Washington, D.C., the extact location to be decided at a later date.

"Two sets of apparatus installed on board vessels of the United States Navy, to be capable of transmitting and receiving messages at all times, in all seasons and in all latitudes, to and from a distance of 1000 miles, and to receive messages from the high-powered station above-mentioned at a distance of 3,000 miles at all times, the apparatus to be capable of transmitting and receiving messages at the maximum radius with entire secrecy and without the possibility of interruption due to atmospheric conditions or intentional or unintentional interference. These sets to include as an adjunct wireless telephone apparatus capable of establishing and maintaining satisfactory communication to a distance between ships of 100 miles. Such communication to be sustained without adjustment of instruments or interruption therefrom for periods of at least 5 minutes. This ship apparatus must be so constructed as to be installed in a room with 100 sq. ft. deck space. The antenna must be so disposed as not to require a change in the height or distance between masts or to materially change the outward appearance of the vessel." [26]

One of the above mentioned "31 paragraphs" reserved the right "to award the contract for either of the items, to accept any bid, to waive any defects or informalities in the proposals, and to reject any or all bids."

When the proposals were finally opened on 28 January 1909, the following bids were submitted:

	Shore station	*Ships equipment*
Marconi Wireless Telegraph Co. of America	$249,245 to $361,094	$15,000
Stone Telephone & Telegraph Co.	$100,000 to $275,000*	
Collins Wireless Telephone Co.		2,450
Radio Telephone Co.	$ 34,250†	$18,700
National Electric Signaling Co.	$182,000‡ $108,900§	
Telefunken Wireless Telegraph Co.	$168,850*	
Massie Wireless Telegraph Co.	$300,000*	

*Bid did not guarantee to meet specifications.
† Equipment only.
‡ Both items and buildings and towers.
§ Both items but not buildings and towers.

On 19 February 1909, the Bureau of Equipment recommended the award of contracts to the National Electric Signaling Co., the "lowest responsible bidder, for the sum of $182,600," which included providing the building and towers. However, when the contract was executed, the second proposal of that company was accepted with the tower and buildings to be erected by the Navy. The contract was signed on 7 May 1909, and included the lease of the company's Brant Rock station, where the apparatus intended for the Washington station was installed for a period of 6

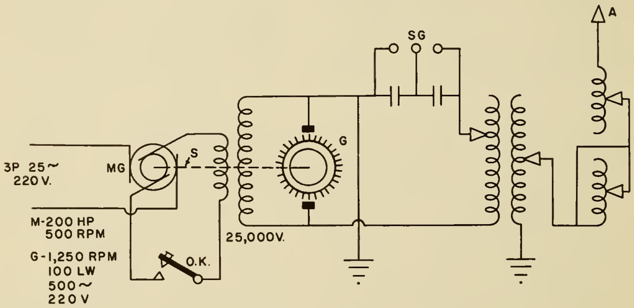
[26] Electrical World (McGraw-Hill Publishing Co., New York), vol. LIII, No. 1, Jan 2, 1909, p. 11.

months for an additional $5,000. This was done for the purpose of experimenting with the equipment as installed at Brant Rock.

Following the announcement of the 19 February recommendation of the Bureau of Equipment, a protest from the Radio Telephone Co. was received wherein they claimed that their bid was the lowest for the apparatus; that the bids for the erection of the station were too indefinite to permit any company to make a satisfactory bid; that the requirements of the specifications were such that they could not be fulfilled by any company; and that no practical wireless telephone could be delivered by any company other than their own because of their ownership of the basic patents on such apparatus; and that their bid on the equipment for two vessels was $18,700, while the bid of the National Electric Signaling Co. was $108,900.[27] The reply

[27] Letter, dated 13 Mar. 1909, Radio Telephone Co. to Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

Schematic Diagram of 100 KW Set Purchased By The United States Navy From National Electric Signalling Company For Installation At Arlington, Va.



SYNCHRONOUS ROTARY SPARK TRANSMITTER

A – ANTENNA
G – SYNCHRONOUS ROTARY SPARK GAP
S – SHAFT
MG – MOTOR GENERATOR
SG – SAFETY SPARK GAP
OK – OPERATORS KEY

Figure 11–1.

of the Bureau of Equipment to this protest, portions of which were quoted in a letter of the Department, was that it was not known that the Radio Telephone Co. had manufactured any radiotelegraph apparatus, although some of their radiotelephones had been purchased by the Navy and that those had proven of doubtful practicability; that the business operations of the company were at least questionable, and the methods they pursued were such as to create grave doubt as to their honest intent; that the comparison of their bid with the bid of the National Electric Signaling Co. was not made with the knowledge of the fact that the latter's bid included equipment for a high-powered station as well as for two sets of ship equipment; that no award was made for radiotelephones; and that it was believed that their protest was made for stock jobbing and advertising purposes. The second letter of the Radio Telephone Co. addressed to the Secretary of the Navy was written in defense of their radiotelephones which had been installed on vessels of the Atlantic Fleet and which according to the Bureau were not favorably reported on. In this letter they stated that they were interested in seeing that the specifications of the contract of 7 May 1909 should be fully met by the successful bidder.

The Marconi Wireless Telegraph Co. of America made no direct protest at this time, but they did, on 24 April 1909, offer the use of their South Wellfleet station for use of the Government at all times or at stated periods.[28]

Repercussions caused by the award of this contract to the National Electric Signaling Co. continued. Several manufacturers charged that Government specifications were being prepared and worded to benefit certain private patentees and a single corporation. In refuting these charges, the Radio Division stated that its specifications for radio equipment were worded so as to incorporate the best features of all manufacturers and to provide for improved construction and were not prepared to favor or exclude any person or firm, but, since the Navy was the largest American user and since the art was developing rapidly, the aim had been to keep the specifications abreast or in advance of the best practices in order to incite further development. The Navy, with its experience with apparatus purchased from various manufacturers, was in the best position to determine the best practices and where improvements were desirable. No radio equipment had been delivered up to this time that completely complied with the latest specifications since it had been necessary to waive some of the specifications on all the bids that had been accepted. Two complete sets then under construction were designed to meet all the specifications, but since the manufacturer had not had previous Government contracts he could not be included in the "certain private patentees and a single corporation." The Telefunken Wireless Telegraph Co. and the National Electric Signaling Co. were delivering material on large contracts and the Wireless Specialty Apparatus Co. was delivering, on contract, receivers and accessories. The most recently awarded contract for complete sets, transmitters, and receivers had been with the National Electric Signaling Co. since they were the lowest responsible bidder on equipment almost complying with and in some respects better than the specifications. No previous intimation that these specifications favored any particular person or corporation had been received, and such charge was without foundation in fact, and also without foundation as regards any award made for equipment delivered on modified specifications.[29] Lower bids of the United Wireless Co. and the Radio Telephone Co.

[28] Letter, dated 24 Apr. 1909, Marconi Wireless Telegraph Co. of America to Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[29] Memorandum, dated 1 Feb. 1911, for the Chief of the Bureau of Steam Engineering, "Concerning Alleged Favoritism Shown in Preparation of Specifications and in the Award of Contracts for Wireless Material, etc.," files, Bureau of Steam Engineering, National Archives, Washington, D.C.

on several schedules were rejected because these companies were not considered commercially responsible. Moreover, difficulties with both these companies had been experienced on previous contracts. Concerning the charge that vessels, stations, and personnel had been used in furtherance of discrimination, the Radio Division felt that this related to the contract for the high-powered station at the seat of government and pointed out that this contract called for no payment until the contractor's guarantees were fulfilled; therefore it was to the interest of the Government to service test this equipment at every possible opportunity. Additionally, the Division advised they were doing all that could possibly be done to encourage research and development by contracting with as many reliable manufacturers as funds would permit. For the past 2 years equipment had been purchased from the Telefunken Wireless Telegraph Co., the Diehl Manufacturing Co., the Wireless Specialty Apparatus Co., the National Electric Signaling Co., and the Marconi Wireless Telegraph Co. of America. Normally the contract had been given the lowest responsible bidder. The Marconi bids were normally higher than those of other companies, but on one occasion they had been given a portion of a contract in order to distribute the work as much as possible and to encourage them to improve their apparatus. It stressed its policy by stating: "Other things being equal, the Navy Department prefers apparatus manufactured in the United States." [30]

Fessenden, having achieved his purpose to some degree, ceased his choleric beratings of the Navy. A study of Navy contracts for radio apparatus indicates that approximately 50 more complete sets of National Electric Signaling Co. equipment were purchased during the next 2 years. This represented about 75 percent of the radio equipment purchased during that period. Excepting for the sales of some apparatus to the United Fruit Co., this represented the total income of the company for this period. The 100-kw. and two 10-kw. equipments were never able to meet the specifications, and settlement was finally effected at a figure below the original contract price.[31]

Fessenden's inability to meet the contractual requirements of the Navy, coupled with his failure to develop a satisfactory radiotelephone system, widened a breech, originally caused by differing personalities, between him and sponsors. In January 1911 this culminated in a complete break, and Fessenden was dismissed. He then sued the company for breach of contract and was awarded a judgment of about $400,000. This forced this company into receivership to conserve its assets, but it continued its research under Mr. Samuel Kinter. In early 1912 Todd, then Head of the Radio Division, in testimony before a Senate subcommittee stated that the company had raised the prices of their apparatus to a point which prohibited the Bureau from making further purchases from them.[32] Shortly after leaving the firm Fessenden became associated with the Submarine Signal Co., of Boston, Mass. From that time he is not credited with further developments in the radio field.

W. Rupert Maclaurin, in his excellent work, "Invention and Innovation in the Radio Industry," states:

> . . . this much is clear about Fessenden as an inventor: in the period from 1905 to 1913 he succeeded in competition with the better organized and aggressive Marconi enterprises, in developing a wireless system which, from a patent point of view, was completely self sustaining.[33]

THE FEDERAL TELEGRAPH CO. OF CALIFORNIA AND THE POULSEN ARC TRANSMITTER

In 1909 Mr. Charles Elwell, an Australian by birth and recently a graduate of Stan-

[30] Ibid.

[31] Infra, ch. XIII.

[32] Testimony of D. W. Todd before a Subcommittee of the Commerce Committee, U.S. Senate, on Radio Communications (Washington, Government Printing Office, 1912), p. 29.

[33] Maclaurin, op. cit., p. 63.

ford University, obtained an option on the American rights to the Poulsen system which had been patented in this country in 1905. The Navy had procured several sets of this apparatus in 1907, and one of the first tasks assigned the U.S. Naval Radio Laboratory was the testing and analysis of this equipment. The Laboratory rendered the opinion that it was too complicated for shipboard personnel to maintain.[34]

In 1910, Elwell and his associates, mostly faculty members of Stanford, formed a small company and constructed stations along the west coast of the United States. Their financial backing was inadequate and the company was soon in precarious circumstances. One of Elwell's partners had been associated with Mr. Beech Thompson, and he managed to gain the interest of that entrepreneur, who subsequently became president of the Federal Telegraph Co., organized to absorb the original company. Elwell became the chief engineer of the new company.

Under Thompson's management the company commenced to prosper and in 1912 established a circuit between San Francisco and Honolulu using 30-kw. arc transmitters and "tikker" detector receivers. The circuit was satisfactory during darkness, and contracts were obtained with the Honolulu papers for the daily transmission of news. The Honolulu station was constructed under the personal supervision of Elwell who, upon his return from Hawaii, convinced Thompson and the other directors that they should endeavor to interest the Navy in their equipment. Elwell proceeded to Washington with a 5-kw. and a 12-kw. set and gave demonstrations. The 5-kw. transmitter was excited by an independent source, whereas the 12-kw. had the field coils directly in series with the arc. The smaller set gave unsatisfactory performance, but the 12-kw. did exceedingly well. The Navy was then testing the Fessenden 100-kw. synchronous rotary spark gap equipment, and Elwell managed to convince the Chief of the Bureau of Steam Engineering and the Head of the Radio Division that the Federal equipment should be given a comparative trial. This was accomplished over the strenuous objection of Dr. Austin, of the U.S. Naval Research Laboratory, who was unable to agree that the 30-kw. transmitter could possibly compete with Fesenden's 100-kw. giant.[35]

Navy officials were so certain that the Federal equipment would be unable to compete with their Fessenden transmitter that they required the company to install its equipment in their new Radio (Arlington), Va. station in such a manner that, after its removal, there would be no evidence of its having been installed. A further proviso required the installation to be completed prior to 1 December 1912.

This equipment did not have to be removed because of failure to compete with the Fessenden equipment. On the contrary, it practically overwhelmed the Fessenden unit, becoming the Navy's darling of the World War I period.[36] The Federal Telegraph Co. soon became a Navy-subsidized firm and was purchased by the Government during World War I.[37]

The first Federal equipment purchased was for the Panama Canal Zone station. The specifications for this equipment were so prepared that only the Federal Co. could meet them. This procedure provoked protests from the Atlantic Communication Co. and the Marconi Wireless Telegraph Co. of America. The substance of the protests was that the specifications restricted competition by describing apparatus that only one manufacturer could supply. This the Bureau admitted to be a fact, and it had been to assure this fact that the proposals had been so advertised. In explaining this,

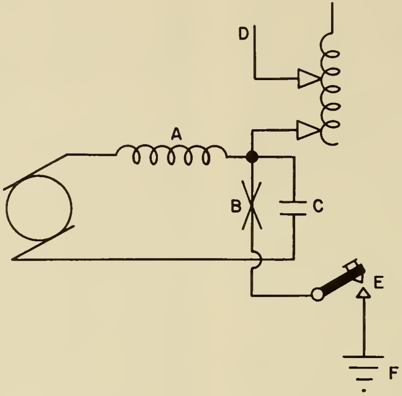
[34] Infra. ch. XIII. L. W. Austin, "The Work of the U.S. Naval Radiotelegraphic Laboratory," Journal of the American Society of Naval Engineers, vol. XXIV, No. 1, February 1912, p. 124.

[35] "Radioana," op. cit., C. F. Elwell, "Pioneer Works in Radiotelegraphy."

[36] Infra, ch. XIII.

[37] Infra, ch. XX.

Schematic Diagram of Federal Telegraph Company 5KW Arc Transmitter

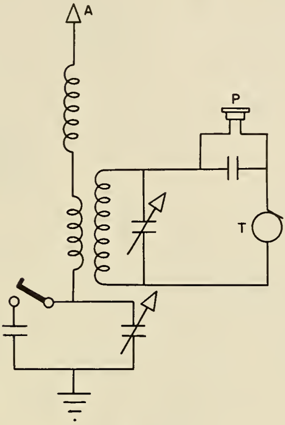


A – ARC SERIES FIELD WINDING AND CHOKE
B – FEDERAL ARC CONVERTER SUPPLIED WITH 500 VOLT DIRECT CURRENT
C – ARC SHUNTING CONDENSER
D – ANTENNA LEAD-IN
E – OPERATING KEY
F – GROUND

Robison's Manual of Radio Telegraphy and Telephony, 1919

FIGURE 11–2.

Schematic Diagram of Federal Telegraph Company Continuous Wave Receiver



A—ANTENNA LEAD-IN
P—HEAD SET
T—TIKKER (SLIPPING CONTACT DETECTOR) FOR PURPOSE CREATING AUDIBLE TONE IN HEAD SET

Robison's Manual of Radio Telegraphy and Telephony, 1919

FIGURE 11–3.

the Bureau noted that it had made extensive investigation of the questions involved and, as a result of its investigation, had specified the apparatus which, in its judgment, would best suit the purposes of the Navy. Such was the ordinary procedure in all commercial transactions. To accept protests to the extent of changing specifications

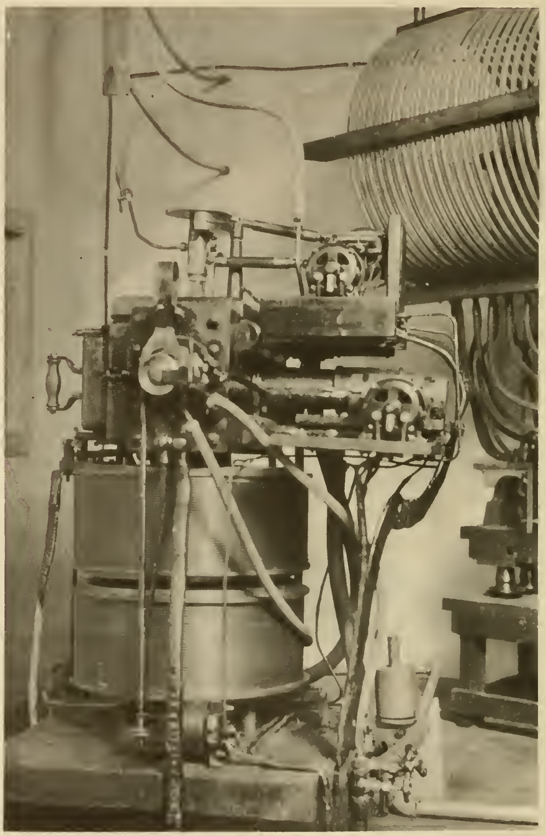


FIGURE 11–4. 30 KW Federal Telegraph Company arc transmitter with helix.

to include apparatus that it did not desire would be to admit that the ordinary commercial procedure was not open to a Government department, whose experience, research, and decisions would thus become secondary to the clamor of rival manufacturers. While the Bureau considered the above protests as an effrontery, it went on to explain its action. There being two fundamentally different systems of radio involved, namely, the spark system or system of damped oscillations and the system of continuous undamped oscillations, sometimes called the Poulsen system, there was a matter of choice. All the other so-called systems bearing proper names such as Marconi, Shoemaker, Fessenden, De Forest, Telefunken, etc., were but variations of the spark system and did not represent real differences so far as fundamental classification was concerned. When comparative tests clearly demonstrated the superiority of the Poulsen system the Navy's course of action was clear. One of the most gratifying features of the situation to the Bureau was that, through the Navy Department's help and encouragement to the Federal Co., which held the American rights to Poulsen equipment, an American company was assisted in developing a system that was to inaugurate a new era in the history of radio. Therefore, in concluding his commentary on the Navy's decision to act as it did, Lt. Comdr. A. J. Hepburn, USN, wrote:

> As the matter stands we alone possess the sure knowledge to foretell a revolution in the art of Radio. That revolution will come whether with or without our help. But whereas on the one hand we stand to gain the credit that comes of clear-cut, scientific investigation, confident judgment and decisive action, taking the leading place in a progressive movement, on the other we are placed in the position of indecision, timidity, self-mistrust—in short, inefficiency.[38]

[38] Letter, dated 3 Apr. 1913, Lt. Comdr. A. J. Hepburn, USN, to the Chief of the Bureau of Steam Engineering, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

THE MARCONI WIRELESS TELEGRAPH CO. OF AMERICA

The early history of this company, its policies, and the Navy's opposition to these have been related in previous chapters. In 1906 it changed its policy to permit outright sale of equipment to the U.S. Navy and submitted proposals for the provision of radio apparatus. The bids submitted by the Marconi Co. were normally higher than those of other companies, but on one single occasion they were given a portion of a contract to distribute the work and to encourage them to improve their apparatus.[39]

This company was not involved in the sale of watered paper, although its stock at times was "hawked" at fictitious prices. It operated at a deficit until 1910.[40] Following the Government prosecution of officials of the United Wireless Company and The Radio Telephone Company and the loss of an infringement suit by United to Marconi, the American Marconi Company became firmly entrenched in the operating field by absorbing both the United and the Massie interests. However, they lagged in research and their equipment rapidly became obsolescent. By 1912 their patent position in the United States had become questionable.

THE ATLANTIC COMMUNICATION CO.

The Atlantic Communication Co. was a totally German-owned subsidiary of the Telefunken Co. established for the dual purposes of acting as the US sales agency of Telefunken apparatus and to operate the US terminal of a proposed transatlantic circuit.

[39] Memorandum, dated 1 Feb. 1911, Radio Division to the Chief of the Bureau of Steam Engineering, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[40] Annual report, Marconi Wireless Telegraph Co. of America.

The contract records of the Navy Department indicate that three 5-kw. and two 10-kw. Telefunken equipments were purchased in 1911. The Navy's principal purchase from this company was a number of quenched spark gaps developed by Mr. Max Wein, of Telefunken. These dischargers enabled the sparks to follow each other so regularly that a musical tone was emitted instead of the sharp staccato sound of the open spark. In addition to increasing transmission ranges by a reduction in the damping effect, the tones of several transmitters in an area could be adjusted so as to be distinguishable. These dischargers came into use rapidly as a modification to existing Navy transmitters. Except for the development of the Poulsen arc this company would propably have become the Navy's sole source for the procurement of transmitters following 1912.

THE WIRELESS SPECIALTY APPARATUS CO.

Upon severing his connections with the International Telephone & Telegraph Co. in 1907, Col. John Firth organized the Wireless Specialty Apparatus Co., New York.

Farnsworth, a radio patent attorney retained by American Marconi, was president of the firm; Firth, with a sales connection with the Fessenden firm, was vice president and sales manager; and J. G. Pickard filled the position of chief engineer, retaining his consultant business and laboratory in Amesbury, Mass.

This company's business was centered around the construction and sales of receivers, Leyden jar condensers, crystals, and other radio components and appurtenances. Their receivers were based upon the developments of Pickard and utilized crystal detectors patented by him. No effort was made to construct transmitters, and this, coupled with their close associations with other companies, permitted them to remain free of involvement in patent litigation for several years.

Their equipment was rugged and reliable, and their business reputation was excellent. With Firth heading their sales branch, they quickly established themselves and sold large quantities of apparatus to the United States and foreign governments. The U.S. Navy purchased their Leyden jars, crystals, and telephone headsets as well as large quantities of their excellent IP 76 crystal detector receivers.[41] These Wireless Specialty Apparatus Co. devices could have been considered Navy standard equipments between 1909 and 1914.

Admiral Hepburn related a story concerning Firth which illustrates his ability as a salesman and also reveals the profits being made in radio equipment at the time.

> The colonel was an engaging character and a great salesman. He used to drop in at least once a month to see us, to see what was going on and to see what he could sell us. I became very fond of the old man. There was no question about it, he wasn't in business for his health and the prices he charged were pretty exorbitant in my opinion, but he had valid patents. It was a matter of detectors which finally made me take a step which has since caused me to wonder about the ethics of the business. We didn't have much money and I finally told him, 'Colonel you will have to bring down the price of those crystal detectors we're buying from you.' We were paying $75.00 a set for them and I judged they could be made for about two dollars and five dollars would have allowed him a fair profit. I said, 'of course, we have to have them and we haven't the money to pay you $75.00 a set. Now what I am going to do is pirate those sets and make them ourselves. We have to have them. You would have a good claim against the government for infringement of your patent and you can go to law about it. In two or three years you can undoubtedly get some compensation, but you will have to pay a good deal of legal fees, but we must have them and unless you do better that is going to happen.' He came back in a few days and said I had him over a barrel, that it was a dirty trick and a few other good-natured remarks of that sort, but thinking it over he thought he could let us have those detectors for fifteen dollars a set. I told him I thought we could do that and we went ahead."

[41] Memorandum, dated 1 Feb. 1911, Radio Division to the Chief of the Bureau of Steam Engineering, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

In early 1912 Firth sold his stock in the company to the United Fruit Co., which then gained control of the firm. Firth then established the Wireless Improvement Co.

SMALL BUSINESS

The only small business concern providing radio equipment to the Navy during this period was one conducted for a short time by an individual named Baldwin. Long after he retired, Admiral Hepburn, in relating his experiences as Head of the Radio Division, Bureau of Steam Engineering, told of his association with Baldwin and of the Navy's role in assisting him to develop the modern set of headphones.

Like every other Government bureau or institution devoted to scientific work, the Radio Division received freak letters from backwoods inventors claiming miraculous discoveries. These were always politely answered, and when someone appeared to have an idea or a device possessing some merit it was promptly investigated. One day, while opening his mail, Hepburn came across a letter from Salt Lake City written with violet ink on blue and pink pad paper. The writer, a Mr. Baldwin, stated that he was sending a pair of telephones, which he had patented, and requested that they be tested. He wrote that they had a resistance of about 2,000 ohms, which he understood was standard for Navy headsets, but he could not be sure because he had no way of measuring it. The phones arrived promptly, packed in an old baking powder tin. They weighed about a pound, and were of radically different construction. The headset consisted of a piece of clock spring affixed to each phone and loosely bound together by hemp twine. Dr. L. W. Austin, of the Navy's Radio Research Laboratory, looked at them and laughingly took them for the requested testing. A few days later he informed Hepburn they were about twice as sensitive as any he had tested and advised him to obtain more for quality tests.[42]

Baldwin was told that his phone had passed numerous tests and that they were within 100 of the 2,000-ohm resistance normally used by the Navy in its phones. He was requested to provide another set for test at the normal price paid for such equipment. He replied immediately on the same blue and pink paper with the same violet ink that he was forwarding another set for which he desired no reimbursement. This turned out to be equally as good as the first. Further correspondence informed him that the electrical properties of his headsets were excellent but that in their existing form they were impractical for use because of their weight and the condition of the head harness. He was advised to redesign and was provided with numerous suggestions which, it was considered, might be helpful. He was told that the Bureau of Steam Engineering was ready to order a quantity of his redesigned phones, provided they cost no more than the Navy was currently paying for similar equipment. He agreed to the redesign and the price, and in a short time developed a satisfactory set of headphones, although the harness was still quite clumsy and uncomfortable to wear.[43]

It then developed that he was manufacturing these devices in his kitchen and, because of his limited facilities and the bonding clause of the Navy contract he would only accept one for 10 sets, after which another contract for 10 more sets would be accepted ad infinitum. These phones were far better than any on the market and the Navy was in a position to take his full limited output, so this procedure was accepted for the time with the hope that a more satisfactory solution would evolve.[44]

After Baldwin had completed several

[42] Transcription of recording by Adm. A. J. Hepburn, S. C. Hooper Reels, Office of Naval History, Washington, D.C., pp. 326–332.

[43] Ibid.

[44] Ibid.

contracts, Hepburn suggested that he endeavor to improve the head harness. Baldwin must have been aware of the desirability of this, for in a very short time he sent in a simple, effective headset consisting of nothing more than two leather-covered spring-wire rods dangling from each end, each of which carried a phone on a spring clip, thus permitting its being slid up and down. In his little kitchen workshop, Baldwin had developed the modern headset, and in the many years which have followed little has been necessary to improve it. Hepburn advised him to obtain a patent upon it immediately but, strangely enough, he replied that he would not demean himself by requesting a patent on such trivia.[45]

The naval radio operators immediately set up a clamor for this comfortable, efficient headset, and this necessitated an increase in manufacturing capabilities. Hepburn suggested he be employed at a navy yard where good facilities could be made available; that he be given a royalty on each set manufactured, and also be allowed to exploit his device commercially. While Baldwin toyed with this idea, there was considerable two-way correspondence with one side of it always in blue, pink, and violet. He finally replied that, for domestic reasons, which Hepburn surmised were more or less peculiar to the Utah of those days, he could not move. At the time the final decision arrived, Firth, of the Wireless Specialty Apparatus Co., happened to be in Hepburn's office.

He was apprised of the situation, and it was suggested that he might, with the Navy's blessing, make some satisfactory manufacturing arrangement with Baldwin. He immediately went to Salt Lake City and succeeded in arriving at an agreement with Baldwin, who closed his kitchen workshop. The contract contained one stipulation, the mention of which in later years was sure to arouse Firth's ire: The company could never increase the price of its headsets sold the U.S. Navy, even at a time when they were selling on the market at a price six times higher.[46]

[45] Ibid.

THE FIGHT FOR COMMERCIAL CONTROL OF THE AMERICAN RADIO INDUSTRY

By the beginning of 1912 an all-out struggle for control of the radio industry in the United States was underway with the Marconi and National Electric Signaling Cos. arrayed against each other and each of these against all others. The National Electric Signaling Co. had won injunctions against both the Telefunken and United Cos., both of which had filed appeals. This company had also filed a damage suit against the Government in the amount of $700,000, claiming infringement by equipment purchased by it from the Marconi and Telefunken Cos. During Fessenden's association with it there had been a close working agreement with the Wireless Specialty Apparatus Co. and Firth had, in some degree, acted as sales agent for both companies. When Fessenden was discharged this relationship ceased and the National Electric Signaling Co. filed an injunction suit against the Wireless Specialty Apparatus Co. The American Marconi Co. had injunction suits pending against the National Electric Signaling, the United Wireless, and the Federal Telegraph Cos. The suit against the latter had been instituted after an unsuccessful attempt by American Marconi to purchase that company in 1911.[47] The British Marconi Co. had a similar suit pending against the U.S. agents of the Telefunken Co.[48]

[46] Ibid. Hepburn stated that he suggested this to Firth to repay him for reducing the price of crystals.

[47] "Radioana," op. cit., letter, dated 12 Dec. 1912, Phillip Farnsworth to F. P. Fish, former president A.T.&T. Co., files, Wireless Specialty Apparatus Co.

[48] Testimony, D. W. Todd before a Subcommittee of the Commerce Committee, U.S. Senate, on Radio Communications (Washington, Government Printing Office, 1912), pp. 28–29.

Only two sizable radio communication companies were then in the field, United Wireless and American Marconi. The former was operating the larger part of the shore stations and had the bulk of the coastwise shipping, while the latter was primarily engaged in providing service for transatlantic shipping. The Massie Wireless Telegraph Co. was providing local service in the Narragansett and Long Island Sound area and a small service on the west coast of the United States. The Tropical Radio Co. was providing service for the United Fruit Co., of which it and the Wireless Specialty Apparatus Co. were subsidiaries.

Following the Government prosecution of the notorious radio stock peddlers, the United Wireless Co. had cleaned house. Yet it was in most precarious circumstances despite having contracts for services with about 450 vessels. Its assets had been misappropriated by its top officers and its patent situation was decidedly questionable.

The two U.S. firms with the most valid and useful patents were the National Electric Signaling [49] and the Wireless Specialty Apparatus [50] Cos. The former company, although not in danger of bankruptcy, was operating under receivership to conserve its assets which had been subjected to severe drain by a court award to Fessenden. The Marconi interests had been advised by their patent attorney, Mr. Phillip Farnsworth, president of the Wireless Specialty Apparatus Co., that their patent situation in the United States was very weak. To strengthen their patent situation they initiated injunction suits.[51]

In a hearing before a subcommittee of the Commerce Committee of the U.S. Senate, both Mr. Cloyd Marshall, of the United Wireless Co., and Todd, of the Bureau of Steam Engineering, testified that should either the Marconi Co. or the National Electric Signaling Co. win all their pending suits they would be in a position to eliminate all competition. At this hearing Todd also testified that, although in the past several years the Navy had purchased considerable radio equipment from the National Electric Signaling Co., that firm had recently increased their prices to an extent that prohibited the Navy from making further purchases from them.[52]

Few of these infringement suits were settled by the courts. The Marconi Co. was unwilling to put its position to a final test. The National Electric Signaling Co. feeling secure of the validity of its newly patented heterodyne method of reception and desirous of conserving assets, did not force for settlements. The Marconi Co. did, however, obtain an injunction over the weak United Wireless Co., forcing it into bankruptcy. Fearing that its stations might fall into the hands of the Navy or that United's stockholders might purchase its remaining assets and revitalize the competition, the British Marconi Co. purchased them for three quarters of a million dollars,[53] an amount far in excess of their value. The shore stations and ships contracts were gratuitously turned over to the American Marconi Co. for operation. The annual lease price of their ship installations was immediately increased to $1,000.

The parent Marconi Co. had just been granted a contract to build a British Empire radio network and was, for the first time, in excellent financial condition. By April 1912 its stock had more than quadrupled in value in an 8-month period. As previously stated, Marconi research and development had not kept pace with the times. In an effort to obtain satisfactory equipment for fulfilling their contract with the British Government, they attempted to purchase the Poulsen patents, but with no

[49] Maclaurin, op. cit., p. 63.

[50] "Radioana," op. cit.

[51] Ibid.

[52] Testimony of Cloyd Marshall and D. W. Todd before a Subcommittee of the Commerce Committee, U.S. Senate, on Radio Communications (Washington, Government Printing Office, 1912), pp. 28–29.

[53] "Radioana," op. cit.

success. They were therefore forced to utilize a Marconi-developed "timed-spark" transmitter.[54] In an endeavor to strengthen the American company and their patent position in the United States they made overtures to purchase the Wireless Specialty Apparatus Co., but these were not successful, possibly because Farnsworth considered American Marconi a "feeble company" and did not desire to exchange his company's stock for theirs.[55] Failing in this, they entered into a patent cross-licensing agreement with the National Electric Signaling Co. wherein they paid the latter $270,000 in royalties and the injunctions which had been granted both companies against each other were dropped.[56] Meanwhile, the Marconi and Telefunken interests had, in 1912, reached a secret world-wide agreement to refrain from instituting litigation against each other.[57]

When the clouds lifted from this struggle, the American Marconi Co. was firmly entrenched in the radio communication field. However, it faced a dissatisfied steamship companies' association no longer forced to lease their equipment in order to be able to communicate with shore stations, since public law required reception of messages from any and all stations.[58] The National Electric Signaling Co. possessed some very basic patents but had but little market. On the other hand, the Federal Telegraph Co. did possess basic patents, and they and the Telefunken Co. were almost the sole sources from which the Navy could procure transmitters. The satisfactory use of the Poulsen arc, which was later procured in large quantities, necessitated the use of the heterodyne receiver patents. This situation posed a dilemma, the solution of which and the resulting repercussions will be related later.

[54] This transmitter proved unsatisfactory and they later tried to procure exclusive rights to a newly developed Alexanderson alternator. The story of the U.S. Navy's struggle to prevent this will be related in later chapters.

[55] "Radioana," op. cit.

[56] Maclaurin, op. cit., p. 68.

[57] "Radioana," op. cit.

[58] Infra, ch. XII.

CHAPTER XII

Achievement of Federal Regulation

THE POLITICAL SITUATION IN 1908

The Senate's failure to ratify the Berlin Convention in 1908 caused all Government departments concerned with radio to intensify their efforts to obtain legislation for Federal supervision of radio usage. The Navy Department continued to provide the leadership in these efforts. The commercial and amateur interests, having won the first round of the struggle, continued their opposition to any legislation which would affect their interests, and they were abetted by a sympathetic Congress, dedicated to and controlled by "big business." Being prior to the ratification of the 17th amendment, this was especially true of the Senate, whose members were appointed by the State legislatures, many whom were controlled by business interests, as reflected by their appointments. A series of articles appearing in some of the 1907 issues of the Cosmopolitan entitled "The Treason in the Senate" stated that 75 of the 90 members were representing "big business" rather than the people.[1]

Before the Government departments would be able to gain success in their efforts to regulate the radio industry, an awakened and aroused public opinion would have to clamor for the enactment of the legislation. Numerous events, some private, some national, and others international in scope, would occur in the several subsequent years which would slowly produce such legislation.

One of the first indications of a changing opinion concerning this control was a shift in the character of the editorials of the Electrical World, the leading electrical and radio trade journal of the period. Prior to mid-1908 these editorials had supported the commercial companies in their fear that Federal control meant Government monopoly. In the 20 June 1908 issue, its editor made the following comments: Only trivial radio service is available due to the lack of concerted effort to make it a worthwhile service; satisfactory tuning devices required development; a more serious and regular employment of radio for practical purposes should not be expected until there was less stock selling and more communications on a purely commercial basis; the primary use of radio should be in oceanic communications and these should be regulated by international action; the whole North Atlantic area should be provided with a network capable of furnishing complete and always reliable communication service; a complete weather service should be established so that vessels might be informed, with a reasonable degree of accuracy, of the weather to be expected within the following 48 hours; information concerning dangers to navigation should be provided; and, by governmental action in this direction, it should be assumed that a considerable part of the benefits would accrue to private enterprise. He concluded this timely analysis of the situation with the statement:

> It is perfectly safe to say that no considerable part of the possible benefits can be realized by private effort. One might as well pin one's faith to a lighthouse corporation instead of trusting such work to a government.[2]

[1] David Sayville Muzzey, "A History of Our Country" (Ginn & Co., Boston, 1942), p. 588.

[2] Electrical World (McGraw-Hill Publishing Co., New York), vol. LI, No. 51, 20 June 1908.

EARLY ATTEMPTS AT LEGISLATION TOWARD SEA SAFETY

The second ("lameduck") session of the 60th Congress convened in early December 1908. There were no early resolutions involving radio introduced to replace those which had died at the adjournment of the first session, and there is no indication that any would have been introduced in this short session had not an event occurred which aroused public opinion.

On 22 January the palatial 15,000-ton White Star liner *Republic* departed New York, bound for Gibraltar and the Mediterranean, with some 440 passengers and a large quantity of supplies for our "Great White Fleet," homeward bound from its triumphant world cruise. The fleet's passage through the Mediterranean had coincided with the earthquake at Messina and large quantities of its supplies had been expended for relief. Running into thick fog, in the early morning hours of 23 January, the *Republic* collided with the Italian *SS Florida*, crowded with 830 immigrants, most of whom were refugees from the Messina catastrophe. The *Republic's* sole radio operator escaped death by the merest chance, the *Florida's* sharp bow having cut into the bulkhead only a few feet from where he slept. His radio apparatus remained undamaged, but the inrushing waters shorted the ship's generators, forcing him to use the emergency storage batteries. He transmitted the message: "*Republic* rammed by unknown steamship, 26 mile southwest of Nantucket. Badly in need of assistance." This was received by the Marconi station at Siasconsett, Mass. This station quickly contacted the *SS Baltic* and *SS La Touraine*, both fortunately being "two operator" vessels. A U.S. revenue cutter was quickly dispatched to the *Republic's* assistance. By daylight as assortment of vessels, informed of the disaster by the Siasconsett station, was gathering at the scene of the collision. About 1,650 persons were transferred from the two ships, with but six reported lost from the *Republic*. Radio played a major role in limiting the loss of life and created such a favorable impression upon the public that it, like life preservers, became considered a necessity by individual sea voyagers.

Within a fortnight of this incident there was considerable editorial comment and clamor. The Electrical World stated that either immediate legislation or revised marine insurance rules which would require all passenger steamers to be fitted with radio equipment was to be expected.[3] The Scientific American commented, in substance, that legislation should be enacted requiring all oceangoing passenger steamers to be fitted with radio equipment.[4] President Roosevelt added his weight to that of the public when, on 8 February, he sent a special message to Congress recommending immediate legislation requiring, within reasonable limits, oceangoing passenger vessels to be fitted with efficient radio equipment. Prior to this, and before 4 February, three separate bills had been introduced before the Congress.

Public opinion was having its effect. By 18 February the House Committee on Merchant Marine and Fisheries had favorably reported out a bill providing a penalty of $300, or 1-year's imprisonment, or both, for failure of any oceangoing vessel, carrying more than 50 passengers and going more than 200 miles, excepting on the Great Lakes, to be fitted with radio equipment and to carry a radio operator. This bill was supported by the commercial interests, for it did not regulate their activities and, if it became law, would enhance their business. The steamship companies, fearing the formation of a radiocombine, argued for a provision against such a possibility. The Commissioner of Navigation urged an amendment requiring all companies to exchange messages in time of distress or emergency. Time was too short to consider controversial issues, especially

[3] Electrical World, op. cit., vol. LI, No. 31, 28 Jan. 1909.

[4] Scientific American (Munn & Co., New York), 6 Feb. 1909.

when such issues concerned business, and the 60th Congress failed to enact the legislation prior to its demise on 3 March 1909.

FIRST RADIO LEGISLATION FOR SAFETY AT SEA AND CONSIDERATION OF REGULATION

Inauguration Day, 4 March 1909, was was marred by one of the worst blizzards ever to hit the National Capital. All communication with the outside world was lost. In its editorial comment upon this condition, the Electrical World noted that although the Government radio station was operative it was little used; the one available private station operated under difficulty due to interference from the Government station; nothing had been accomplished to permit tuning to allow two nearby stations to operate without interference; the amateurs were using more powerful equipment and were thereby adding to the chaotic condition and should be controlled by Government regulation; action should be taken to insure the availability of radio for emergency use under such circumstances. Continuing, the editor again deplored the lack of accurate tuning to help in alleviating the problem. While receiving stations might be able to tune out interference from certain transmitters, they could not remain in contact with shipboard apparatus over any considerable distance if bothered by numerous amateurs operating on a wide variety of frequencies. As additional vessels became equipped with radio, and depended more and more upon it, the situation would grow more complicated and serious. In the use of equipment this could mean the difference between life and death. As frequent as interference might be at other times, it was assumed that most persons possessed sufficient sense of responsibility to refrain from interfering with distress communications, but there would always by a few irresponsible people. In closing, he warned:

> It is high time to undertake friendly but extremely thorough regulations, for amateur seaboard stations are much in the position of amateur lighthouse plants, interfering with the legitimate safety precautions with respect to navigation, which are peculiarly the business of government. It may be contended that private persons have the right to experiment even with lighthouse lenses, but granting this, they should be compelled, and can be legally compelled, to desist from so experimenting as to interfere with navigation. Congress has ample powers under the constitution to pass federal statutes forbidding any and all acts inimical to public safety and federal authority is fully competent to enforce them. With the present tendency to make the installation of wireless apparatus compulsory on ocean-going passenger vessels, close regulation becomes imperative.[5]

President Taft called the 61st Congress into special session on 15 March 1909 solely for the purpose of redeeming the Republican Party's promises of tariff reform. During this session, Senator Frye, of Maine, chairman of the Senate's Commerce Committee, introduced a bill similar to the one upon which the 60th Congress had taken no final action. This differed only in that the penalty for violation was a fine of $2,000, and the steamship companies were afforded the protection they had previously sought by the following proviso in the penalty clause:

> That it shall constitute a good defense to a prosecution under this act for the defendant to show that the corporation supplying efficient apparatus for radio-communication have entered into a combination for the purpose of maintaining or enhancing the rental price of such apparatus.

Congress was completely occupied by the tariff legislation until August and other business was deferred.

During the passing months, public opinion was gradually shifting to the position held by the Government departments. An editorial appeared in the Electrical World[6] advising its readers that the Frye bill, in itself, was insufficient, and pointed out that its column had, several times, taken up the need of proper regulation by the Govern-

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[5] Electrical World, op. cit., vol. LII, No. 37, 11 Mar. 1909.

[6] Electrical World, op. cit., vol. LIV, No. 19, 4 Nov. 1909.

ment over the hundreds of amateur, commercial, and Government radio stations which "daily afflict the overburdened ether with their sputtering."

Late in 1909, Congressman Roberts, of Massachusetts introduced House Joint Resolution 95, which in the light of subsequent history must be considered the most sensible proposal made, to that time, for the solution of the radio-usage problem. It proposed the creation of a board to be assigned the task of preparing, within 30 days of its organization, a comprehensive plan to govern the operation of all radio stations under the cognizance of the United States, with due regard for all. Under the measure, the board would have consisted of seven members, one each from the War, Navy, and Treasury Departments, three from commercial interests, and one unbiased scientist.

This resolution was far more in keeping with the needs of the Government and the suggestions of the Electrical World. That journal praised it highly, stating that the need of regulation was a "crying one" and further observed:

> As pointed out by Representative Roberts, the abuse of the present freedom of wireless operation on the part of amateurs is abominable, not only through interference with commercial working but, not infrequently, in violation of decency.[7]

This publication continued its weekly editorials in support of the measure and constantly invited attention to its salient features and to the necessity for enactment of legislation to remove the causes of the chaotic condition.

On 16 February 1910, hearings on the Roberts resolution commenced before a subcommittee of the Committee on Naval Affairs of the House of Representatives with Congressman Roberts presiding. All interested companies had been requested to send representatives, and no individuals were barred from making comments or suggestions. Mr. Roberts opened the hearings with the following statement:

> The resolution was introduced by myself, and I wish to state that the only purpose in my mind in introducing this legislation was to bring about some reasonable regulation of the air in the interest of not only the government service in wireless, but of the commercial and the amateur as well. I judge, from communications I have received and from articles I have read in papers, that there is an impression in the minds of the amateurs of the country that the purpose of the bill is to put them out of business entirely. I wish to disabuse their minds of that idea; it is not to prevent any person having a right to use the air for wireless communication from so using it, but simply, through a board, to make appropriate regulations to control that use of the air so that one will not be needlessly and unecessarily interfering with the other, that all will have their rights. I presume you gentlemen recognize the fact that we are entering, in this proposition, upon new territory entirely from a legal standpoint. It has always been understood that a man owning real estate owned to the center of the earth and the heavens above and controlled everything above and below the surface of the piece of land that he happened to own. We have been brought up with the idea that the air was absolutely free to everyone; but the march of civilization has brought about conditions, particularly in this matter of wireless communication, that render it imperative, in my estimation, that there be some change of the old common law with regard to rights in the air, in the interest of modern progress and development. I apprehend we may meet with some difficulties in attaining that end by reason of this radical change from the old law on the subject of uses of the air.[8]

In support of his bill, Mr. Roberts presented a large mass of matter he had collected relating to the need of regulation and listed innumerable instances "of interference on the part of Government operators with commercial operators, on the part of commercial operators with Government operators, and on the part of amateurs with both commercial and Government operators." Assuming the necessity of some means of control, he felt that the principal question to be taken up by the committee was the modus operandi of accomplishing the task. Being of the opinion that the committee would be provided with the "very cream of experience and knowledge in the

[7] Electrical World, op. cit., vol. LIV, No. 26, 23 Dec. 1909.

[8] "Hearings Before a Subcommittee of the Committee on Naval Affairs of the House of Representatives on H. J. Res. 95" (Washington, Government Printing Office, 1910).

art of wireless communication," he felt that the opinions and views of those present would enable the legislators " to arrive at the proper method of going about the subject." [9]

The chief objectors to the Roberts proposal were the National Electric Signaling Co., the Massie Wireless Telegraph Co., the amateurs, and the manufacturers who provided them with their equipments. The Marconi interests did not send a representative to the hearings. The supporters of the measure were the United Wireless Co., the Radio Telephone Co., and the Government departments.[10]

Volumes of testimony were taken or accepted in the form of briefs by the subcommittee. Those who objected to the proposal were, for the most part, merely repeating their objections as previously raised at the hearings on the ratification of the Berlin Convention. They were summarized by the opposition's spokesmen, the representatives of the National Electric Signaling Co. They noted that the Government representatives had mentioned a complete system of regulations for the control of radio which had been drawn up at Berlin. Even though the Conference had been attended by radio experts from the military and naval services of many governments as well as by men understood to be scientists, and who produced a most elaborate scheme of regulation, this scheme was not adopted by the United States, in spite of the fact that adoption was most vigorously urged by the Government representatives before the Senate Committee on Foreign Affairs in 1908. In that Convention there were three or more regulations which the National Electric Signaling Co. felt, had they been adopted, "would have prevented most important improvements that have been made in the art and are employed in it today by the Army and Navy as well as by commercial interests." The firm believed that the regulations formulated by the Berlin Convention provided a fine example of what might be expected from the proposed committee. Therefore, if a board were permitted to prepare a comprehensive scheme of regulation, it would impede and interfere with the progress of the art. From a purely selfish motive, the firm admitted, it was convinced that it could practice wireless telegraphy without fear of interference from anybody. "All that we ask is to be let alone—to have no rules or regulations made." [11]

The amateurs were loud in their objections. They sent in numerous resolutions voiced against the measure and expressing the fear that amateurs would be legislated against to the extent that they would be placed in a status which would almost completely prohibit their activities. They were supported and abetted by manufacturers who feared that legislation controlling amateur usage would eliminate a profitable portion of their businesses.[12]

Several individuals, claiming status as experimenters, had a representative appear before the committee and file a brief which in essence requested consideration for membership on the proposed board.[13]

The supporters of the measure pointed out the need of regulation and of adherence to the Berlin Convention. They submitted hundreds of pages of radio logs and correspondence in support of their contention that the air was full of vituperations, obscenity, and unnecessary transmissions.[14]

By 31 March the Roberts bill had been

[9] Ibid.

[10] Ibid. The United States Wireless Co., engaged mostly in providing radio communications for coastwise shipping along the Atlantic, Gulf, and Caribbean sea-coasts, had discovered that the maintenance and operation of the required number of coastal stations depleted the profits obtained by leases of shipboard equipments. They, therefore, favored Government ownership and operation of such stations ("Radioana," Massachusetts Institute of Technology, Cambridge, Mass., memorandum, dated 12 Feb. 1912, J. L. Hogan, Jr., to General Manager, National Electric Signaling Co., files, National Electric Signaling Co.).

[11] Ibid.

[12] Ibid.

[13] Ibid.

[14] Ibid.

favorably reported out by the Committee on Naval Affairs and was expected to come up for consideration. Several bills had been urged in opposition to it, among them one by Congressman Peters and another by Congressman Burke. Every week brought forth new editorials and letters. The responsible trade publications continued to support the Roberts resolution, but many contrary opinions were expressed. Almost all of these recognized the increasing menace created by the small percentage of amateurs who were irresponsible.

While the House subcommittee had been conducting hearings on the Roberts bill, the Senate passed the measure introduced by Senator Frye. On 20 June 1910, the House also acted favorably on this measure. It was approved on 24 June as Public Law No. 262, commonly known as the Radio Ship Act of 1910, and became effective on 1 July 1911. This law required that, beginning with its effective date, all ocean-going vessels carrying 50 passengers or more be fitted with efficient radio apparatus, capable of transmitting messages over a distance of at least 100 miles, day or night, and staffed by 1 skilled operator. It was not applicable to vessels plying between ports less than 200 miles apart nor to shipping on the Great Lakes.

Although the enactment of this legislation was desirable and a necessary, though inadequate, measure for the protection of life at sea, it increased the number of stations but did nothing to regulate their usage or to compel intercommunication between commercial companies. Unbridled, the amateur, the commercial, and the Government operators continued to vie with each other and among themselves for air time. The chaotic conditions increased until open warfare, consisting mostly of vituperation and obscenity, took over as much time as did the transmission of legitimate correspondence. However, the passage of this act apparently reassured the public, as evidenced by a diminution of editorial comment for the next few months. This relieved the pressure on a Congress which had no desire to antagonize business interests further. Considering that it had done its duty, Congress went on to adjournments of both this and its second session without action on other radio measures.

THE EFFECT OF A CHANGING POLITICAL SITUATION

The Republican Party had been in power since early 1897. Shortly after the Taft administration came into office in 1909, dissension commenced as a result of the failure of Congress to represent the people. This political revolt culminated in the 1910 elections, when the Democrats obtained control of the House and reduced the Republican majority in the Senate to the point where, with about a dozen insurgent Republicans, they effectively controlled that Chamber.[15] Big business interests lost their power to control the enactment of legislation. This enhanced the possibility of obtaining some measure of Federal control over the use of radio. However, this Congress was not called into special session and, therefore, did not convene until the first Monday in December 1911.

THIRD INTERNATIONAL RADIO TELEGRAPHIC CONFERENCE INVITATION WITHDRAWAL FORCES SENATE TO RECONSIDER BERLIN CONVENTION

In the latter part of 1911 arrangements for the Third International Radio Telegraphic Conference, scheduled to be held in London during June 1912, were being pushed to conclusion. Since the United States had failed to ratify the Berlin Convention of 1906, its adhering members deemed it necessary to withdraw the invita-

[15] Muzzey, op. cit., p. 601.

tion to this country to participate.[16] The Senate Committee on Foreign Relations, awakening to the fact that its two immediate predecessors had left some unfinished business, hastily removed the treaty from its "pigeonhole" and on 21 February 1912 began reconsideration of its ratification. In commenting upon this, the Electrical World stated:

> The International Wireless Telegraph Convention will again convene in London during the month of June this year. Although no government, through its representatives, had a more prominent part than the United States in framing the terms and regulations of the Convention organized in Berlin in 1906, yet the Senate has steadfastly ignored its ratification. When the invitation to our Government to participate in the London Convention was withdrawn, the Senate Committee on Foreign Relations awakened to the fact that from a wireless standpoint this country was an outcast among the nations and hastened to make amends by reporting the Treaty out of the committee. As there is no serious opposition, the Treaty will probably receive favorable action in the Senate, and delegates representing the State, War and Navy Departments and the commercial interests will be appointed to attend the London Convention.[17]

The hearing to reconsider the ratification of the Berlin convention was of but few hours' duration. The National Electric Signaling Co. offered the sole opposition to ratification. Their objections were the same as in the 1908 hearings and can be summarized by the following excerpts from a brief filed by its general manager:

> It is unjust to the companies who have developed wireless telegraphy.
>
> It is not practical.
>
> Its restrictions are of such a character as to prevent future development of wireless telegraphy.
>
> It forbids the use of a number of most important developments in wireless telegraphy.
>
> It is premature. The art is young and should be allowed to develop unrestricted. No one can say at present along what lines it will reach its greatest degree of perfection.
>
> It is believed to involve acts that are opposed to the Constitution.[18]

Rear Adm. John R. Edwards, USN Inspector General of machinery for vessels building on the Atlantic coast, was designated by the Navy Department to present the Government's reasons in advocating ratification. His able and forceful testimony, together with his prepared brief and complete rebuttal of the opposition's testimonies as presented in the 1908 hearings,[19] were instrumental in having the Convention favorably reported out of committee.

RATIFICATION OF BERLIN CONVENTION AND RENEWAL OF INVITATION TO ATTEND THE LONDON CONFERENCE

After more than 5 years of delay and after all the other signatory powers had ratified the Convention, the Senate approved the treaty on 3 April 1912. Following the formal notification of ratification, the invitation for the U.S. Government to send delegates to the Third International Radio Telegraphic Conference was reextended.[20]

REVISION OF THE RADIO SHIP ACT OF 1910

Just prior to the convening of the 62 Congress occurred one of several incidents pointing out the inadequacy of the Radio Ship Act of 1910. At 0345, 23 November,

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[16] It is possible that this was the result of a "behind the scenes" maneuver by the U.S. Department of State to force the Senate to take action on the Berlin convention. This contention cannot be supported by evidence, but it would appear unlikely that an invitation once issued, in full knowledge that the U.S. had not ratified the treaty, would be withdrawn.

[17] Electrical World, op. cit., vol. 59, No. 10, 9 Mar. 1912.

[18] "Hearings Before the U.S. Senate Committee on Foreign Affairs on Ratification on the 1906 Berlin Radio Telegraphic Convention" (Washington, Government Printing Office, 1912).

[19] Ibid.

[20] Electrical World, op. cit., vol. 59, No. 15. "Ratification of the Berlin International Wireless Telegraph Convention."

1911, the steamer *Prinz Joachim,* bound from New York to Jamaica, struck a reef near Atwood's Key, the most easterly of the Bahama group. Radio calls brought early responses from six shore stations, including one at New York, 1,100 miles distant, but not a single ship answered. When the passengers discovered that a large number of ships carried but one radio operator, who normally slept between the hours of 0130 and 0600, they were indignant. They voiced the opinion that such a situation required change and that each ship should be forced to carry several operators, standing round-the-clock watches. A ship was contacted about 0900, about 80 miles away, but it refused to lend assistance. It was not until after 1400 that the Ward liner *Virginia* answered and approached to rescue those on board.

The Honorable William Jennings Bryan was one of the rescued passengers. He was extremely influential with the members of the 62 Congress, and in the following spring he did much to speed the drafting of a bill of amendment to the Radio Ship Act of 1910. This, and several other bills pertaining to necessary Federal regulation of radio communications, were being studied by Congress when occurred one of the greatest peacetime disasters in maritime history.

In the early hours of 15 April 1912, the White Star liner *Titanic,* then on her maiden voyage, struck an iceberg and sank. The world was stunned at the sudden and tragic end of the newest, largest, most luxurious, and "unsinkable" 46,000-ton, $12 million masterpiece of shipbuilding. The most astounding part of the calamity was that on a clear, calm, beautiful, starlit night, with scarcely a ripple on the surface of the sea, and with nearly 3 hours in which to abandon ship under ideal conditions, over 1,517 human beings, men, women, and children, including a long list of prominent figures in the arts, public life, and business world, met death in the icy waters over the Grand Banks of the North Atlantic. Tragically, there were ships within range of the *Titanic* that did not know of her plight because they either were not equipped with radio or employed a single operator. The 6,000-ton Leyland liner *California* had stopped to await daylight before steaming through a field of drifting ice, and was not more than 20 miles from the disaster secene. Its operator, a 20-year-old, $20-a-month radioman, had tried to inform the Titanic's operator of the situation, but had received a curt, "Shut up, I'm busy with Cape Race." Following this rebuff, and after having been on duty 16 hours, he continued to listen for a few minutes longer, and then secured his equipment. Had he remained on duty, he should have heard the distress signal and the *California* could have cautiously covered the distance in time to be of invaluable assistance. Other ships received the *Titanic's* distress signals. The first to answer was the German SS *Frankfort,* 153 miles to the southwest, and the slow-speed *Carpathia,* 58 miles away, whose operator happened to be on watch, long after his time was up, because he was interested in picking up some news from Cape Cod. The *Carpathia,* under forced draft, hurried to the rescue of 712 of the survivors. Few pages of history record a more gallant effort than that of the *Carpathia's* captain, Arthur Rostron. His amazingly complete preparations and his accomplishment were later praised by the U.S. Senate Investigating Committee as a "marvel" of foresight and masterly organization. The radio operator of *Mount Temple,* 50 miles distant, was preparing to secure his equipment when he picked up the frantic message. She immediately proceeded to assist, but when within approximately 14 miles of the sinking vessel she was stopped by the same icefield that had stopped the *California.* The *Baltic* and the Russian SS *Birma,* also converging on the ice-littered area, were forced to await daylight.

The disaster served to point, with terrible directness, to the absolute necessity of regulating the use of radio. Great as was the loss of life, without radio there might not have been a single survivor. A few more hours, the roughening sea and increasing cold would certainly have decreased the list of survivors. The succeeding 24 hours demonstrated only too clearly that lacking rigorous regulation radio was far less effective than it might have been. The *Carapathia* and the shore stations experienced difficulty maintaining communications because of the constant interference from chattering operators.[21]

Following the *Titanic* disaster the bill amending the Radio Ship Act of 1910 was quickly passed and became Public Law 238 of 23 July 1912. This amendment to Public Law 262 of 24 June 1910 included shipping on the Great Lakes; required auxiliary power supply, independent of the vessel's main electric powerplant, capable of enabling radio apparatus to be operated continuously for at least 4 hours at a minimum range of 100 miles, day or night; and, made it compulsory for ships to carry two or more persons skilled in the use of such apparatus.

THE GOVERNMENT'S CONTINUED EFFORT FOR ENACTMENT OF REGULATORY LEGISLATION

Lt. Comdr. David W. Todd, USN, became the Head of the Radio Division, Bureau of Steam Engineering, in 1910, and shortly thereafter became the spokesman for the Government departments in their struggle to obtain regulation. He was not unaware of the change in congressional attitude. In the period preceeding the convening of the new Congress, he and his associates were active in pushing regulatory legislation. In a paper entitled, "The Navy's Coast Signal Service," delivered before the American Society of Naval Engineers, 14 November 1911, he clearly stated the Government's position relative to the control of radio. This paper is quoted in part:

> There is no law, nor order and with an increase of the number of commercial shore stations conditions will be chaotic. Any wireless company, any individual, can put up a station anywhere, of whatever power or range it or he may please. Any wave length may be used, any kind of transmitter. There is no restriction as to hours of working. The time signals sent out by naval stations, the information concerning wrecks, derelicts, ice, aids to navigation displaced, storm warnings, all are subject to interruption by neighboring stations, and the mariner may listen for them in vain. Vessels in distress may not be able to make known the fact or extent of their plight or their positions, on account of press dispatches being relayed along the coast, or a long invoice of goods being repeated by wireless, for advertising purposes, between cities separated by a twenty-five-cent telegraph rate. The government station, most useful to shipping of all kinds, may be seriously handicapped by malicious interference. Not only are land stations troublesome to each other, but ship stations are poorly managed. Ships in harbor use their sets for needless work with a station sometimes less than a mile away. They send position reports too frequently. The operators engage in personal chatter.

Todd advocated a law licensing all stations by the Department of Commerce and Labor and under regulations to be framed by it. The proposed law included the following: The hours of operation of a station; the power to be used, depending on the business for which the station is licensed; the frequencies authorized; the type and degree of efficiency of the apparatus; a prohibition against ships using their sets within certain limits when making or leaving port, except in emergencies; a prohibition against shore stations using radio between points covered by landwires; and a requirement that all coastwise stations be opened to international traffic under the rules established by the Berlin Convention. Commenting upon the last item, he pointed out that various nations had sent representatives to the Berlin Conference, where plans had been developed for international wireless communications between ship and shore. These plans included arrangements for satisfactory radio communications between vessels, for the use of radio in succoring vessels in distress, and provided the means whereby any individual on radio-equipped vessels could send a message via a coast station of any

[21] Electrical World, op. cit., vol. 59 No. 17, 27 Apr. 1912.

country and prepay charges on board. He stated that while the United States was well represented at the Conference, was given ample opportunity to express its views, and was largely responsible for the framing of the Convention, the results had been fruitless for this country. The commercial firms had been powerful enough to block its ratification by the Senate, and the United States had become an international outcast insofar as radio operations were concerned. He stated that:

If a foreign ship or station accepts a message from an American ship it is through courtesy only. One of the greatest nations of the world, with thousands of miles of sea coasts, with outlying island possessions, one whose stations will always be a factor in facilitating and guarding the safety of the world's commerce, is without standing. Foreign vessels on our coast get no response to their calls, or are told that a certain station takes messages from certain ships only, or in the case of a naval station, that any message will be forwarded 'Collect' only. This cannot go on.

Continuing, Todd suggested that it would be better if the Navy provided all shore stations for commercial radio communications with ships and stated that a chain of stations under a single control would result in a minimum of interference and provide a maximum of satisfactory communications with ships at sea, which he saw as the true field for radio. For military purposes and for certain oversea work, radio communications between shore stations was feasible and necessary, but he believed all relaying of messages between points adequately connected by landwire should be reduced to a minimum and that this should be required by law. He considered that any radio concern proposing to operate overland, in competition with the telephone and telegraph companies, was either extremely optimistic or was not acting in good faith. While another international convention was close at hand at which the United States would probably be as well represented as in the past, he opined that the arguments of the commercial companies would prevail and color our position since our Government, as a whole, had not yet realized the importance, the tremendous possibilities, and the astonishing growth of the new medium during the past decade.[22]

THE ACHIEVEMENT OF FEDERAL RADIO REGULATION

The ratification of the Berlin Convention necessitated the enactment of legislation to insure the carrying out of its accepted provisions. In anticipation of this ratification, the Bourne bill had been introduced in the House and, at about the same time, two measures, S 3620 and S 5630, were introduced in the Senate. After studying the two Senate proposals and conducting hearings, open to all concerned, a subcommittee of the Committee on Commerce considered that both bestowed undesirable powers upon the executive departments of the Government and gave too-great privileges to military and naval stations, while failing to define accurately the limitations and conditions under which commercial enterprises could be conducted. At the subcommittee's direction, S 5334, a substitute bill, was drafted by the Government departments and introduced on their behalf.[23]

The Government interests supported the substitute measure. Todd was ably assisted by Dr. L. W. Austin, head of the U.S. Naval Radio Laboratory; Mr. E. T. Chamberlain, Commissioner of Navigation, Department of Commerce and Labor; and Maj. S. O. Squiers, Signal Corps, USA. The opposition was comprised of the Marconi Wireless Telegraphy Co. of America, the National Electric Signaling Co., and the United Fruit Co., all of which filed briefs of objections and had representatives present at the hearing. Mr. Richard Pfund, manager of the Telefunken Wireless Telegraph Co.,

[22] Journal of the American Society of Naval Engineers, vol. XXIII, No. 11, November 1911, p. 1096.

[23] "Report to Accompany S 6412, 6 May 1912" (Washington, Government Printing Office, 1912), pp. 2–3.

did not appear, but addressed a letter to Senator Bourne, the subcommittee chairman, recommending passage with some minor changes. Mr. Charles H. Stewart, representing the Wireless Association of Pennsylvania, the only amateur organization having representatives present, filed a brief recommending minor changes and stating that they preferred legislation along the lines which had been envisioned by the commission plan of the Roberts bill. He pledged his organization's support of any legislation which would bring about the proper observance of necessary controls.[24]

The hearing was conducted under amicable conditions, with the subcommittee exercising considerable patience in an endeavor to obtain all points of view in order to amend the bill in the best interests of the people of the United States.[25] The viewpoints of the opposing factions, as submitted by their briefs, were not materially different from those presented at hearings on previous proposed legislation. However, in the oral testimony there was more an air of understanding and willingness to compromise on the part of all witnesses.[26]

The changes made in S 5334, before it was enacted into Public Law 264, 62 Congress,[27] were relatively minor in most aspects. The new law required the licensing of commercial and amateur stations and operators and included a provision for the collectors of customs of ports to issue temporary licenses to operators sailing on vessels as reliefs for regularly assigned but unavailable operators. The proposed bill had required that only naval and military stations receive distress signals, but the law, as passed, made no distinction. Changes were made to the regulations as originally contained in the measure, some which were considered desirable by the commercial interests and which were acquiesced to by the Government departments, such as a requirement for secrecy of context of messages; the reservation of the first 15 rather than the first 30 minutes for Government traffic in locales where interference made time division a necessity; the elimination of the Government silence signal; the addition of a mandatory requirement that all stations give absolute priority to distress signals and traffic; the limitation of amateur usage to the band above 1500 kc. instead of 1,000 kc.; the requirement that a ship station would normally communicate with the nearest shore station; and the establishment of more stringent penalties for violations. Commercial interests had endeavored to restrict the Government to a band between 333 and 500 kc. in lieu of the proposed 300 to 500 kc. band, but they were not successful. Naval stations were authorized, insofar as consistent with the transaction of Government business and whereever necessary because of the lack of a commercial station within 100 miles, to handle commercial messages, collecting tolls thereon, and depositing such funds with the U.S. Treasury Department as "miscellaneous receipts." [28]

The Titanic disaster has often been given as the compelling reason behind the enactment of this legislation. This is not correct. The subcommittee of the Senate Commerce Committee had completed its masterful work of bringing the opposing views into proper focus and the bill had been reported out prior to the disaster. It did, however, awaken congressional eyes to its wisdom and necessity and insured its final enactment.

In closing this narrative of the decadelong effort, to establish a semblence of circuit discipline, no better tribute can be paid the final action than to quote a statement made a few months later by Mr. John

[24] "Hearings on S5334, Radio Communications, Before a Subcommittee of the Committee on Commerce, U.S. Senate, 1 Mar. 1912" (Washington, Government Printing Office, 1912).

[25] Ibid.

[26] The changes in attitude between the oral testimonies and the filed briefs, which had been prepared earlier, were occasioned by the realization that the Senate would ratify the Berlin Convention.

[27] App. G.

[28] "Public Law 264, 62 Congress," (Washington, Government Printing Office, 1912).

Bottomley, who had represented the Marconi interests at the hearing:

> While it is true that the laws enacted are not ideal and that more deliberate action would undoubtedly have produced a better result, it must be admitted that the lanes of the ocean have been rendered safer. . .[29]

THE THIRD INTERNATIONAL RADIO TELEGRAPHIC CONFERENCE

The Third International Radio Telegraphic Conference convened in London on 4 June 1912. The American delegation was headed by Admiral Edwards, who had so ably supported the ratification of the Berlin Convention. Another United States delegate was Todd, who had been the Government spokesman at the hearings resulting in the enactment of Public Law 264. He had been relieved as Head of the Radio Division of the Bureau of Steam Engineering in order that he could devote full time to this duty and to additional duty as personal aid to Admiral Edwards. Other members of the delegation were Dr. Louis Austin, head of the U.S. Naval Radio Laboratory; Majs. George O. Squier, Edward Russel, and Charles Saltzman, Signal Corps, USA; Mr. John I. Waterbury, who had attended the previous conferences; Dr. Arthur G. Webster, professor of physics, Clark University; Mr. John Hays Hammond, Jr., who, within a few years, would become famous for his successful application of the radio control of objects; Mr. William D. Terrell, Chief Radio Inspector, Department of Commerce and Labor; and Prof. Willis L. Moore, Chief of the Weather Bureau, Department of Agriculture. These delegates were all extremely well qualified to represent the United States in this Conference and had been selected with extreme care in order that this country might maintain the prestige which the delegates had established for it at the Berlin Conference, some of which had been lost in the long delay in ratification.[30]

Twenty-nine nations and eight dominions and colonies, all with voting powers, were represented at this Conference. With the exception of Mexico, all the nations which had subscribed to the Berlin Convention were represented. The 1903 Conference had been attended by 9 nations and the 1906 Conference by 27.[31]

Since the Conference was called to revise a convention framed to promote the efficent use of radio for commercial uses, most of the delegations were made up of officials and experts of the various post and telegraph departments. Because of the great importance of the art as an instrument of war, the military element composed about one-third of the delegates. About one-sixth were technical personnel of special attainments in scientific fields. To watch matters concerned with national policies, some delegations had diplomatic officials of high standing.[32]

Over 200 propositions were submitted by the various delegations, many of which were duplicates or represented different expressions of the same fundamental problems. The excellent work of the Berlin Conference made it unnecessary to amend radically the existing convention. Although it was thoroughly revised to bring it up to date, the additions were of more importance than the changes.[33]

The American contingent took an advanced view of the possibilities of increasing the number of circuits in a given area by a requirement for sharp tuning. Other nations were not ready to accept this view because of the lack of transmitting equipment capable of being adjusted to transmit over a narrow band.[34]

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[29] Electrical World, op. cit., John Bottomley, "Commercial Wireless Telegraph Development," vol. 63, No. I, 3 Jan. 1914, p. 25.

[30] Journal of the American Society of Naval Engineers, December 1912, D. W. Todd, "The International Radio Conference of London," p. 1330.

[31] Ibid., p. 1330.

[32] Ibid., p. 1333.

[33] Ibid., p. 1340.

[34] Ibid., p. 1342.

Following so close after the *Titanic* disaster, the Conference gave great attention to regulation pertaining to safety at sea. The following new regulations were added to this Convention:

The maintenance of a continuous radio watch by certain ships;

Specified periods of compulsory "listening-in" by ships not required to maintain constant watch;

A compulsory requirement for vessels to be fitted with auxilliary apparatus capable of working six hours, independent of the ship's boiler supply.

A compulsory requirement for cessation of transmission during the "listening-in" periods.

A compulsory requirement that radio operators and apparatus be directly under the authority of the captain; and

A requirement that all radio transmissions in the vicinity of a ship in distress be under the control of that ship.

All of these items, with the exception of the one requiring "listening in" periods for ships not maintaining a continuous watch, were tabled by the U.S. delegation.[35]

The Convention added a requirement for priority transmission of weather and time signals to ships upon request and, additionally, required that other ships in the area refrain from transmitting during these transmissions. Another addition included the assignment of the first letters of the present call system to the various adhering nations.[36]

While the London Conference did not regard itself competent to go beyond recommending the compulsory equipping of ships and the erection of additional coast stations, it did unanimously adopt the following resolution:

The International Radio-Telegraphic Conference having examined the measures to be taken with the view of preventing disasters at sea and of rendering assistance in such cases, expresses the opinion that, in the general interests of navigation, there should be imposed on certain classes of ships the obligation to carry a radio-telegraphic installation.

As the Conference had no power to impose this obligation, it expresses the wish that the measures necessary to this end should be instituted by the Governments.

The Conference finds it important, morever, to ensure, as far as possible, uniformity in the arrangements to be adopted in the various countries to impose this obligation, and suggests to the Governments the desirability of an agreement between themselves with a view to the adoption of a uniform base for legislation.[37]

Immediately prior to the close of the Conference on 5 July 1912, in compliance with instructions from the U.S. State Department, and in consideration of the expressed desires of several of the delegations, an invitation was extended to hold the next conference at Washington. This invitation was greeted with acclamation. It was first suggested that the date be fixed for 1915, the year of the official opening of the Panama Canal, but the conferees considered that a minimum of 5 years should elapse between conferences.[38]

[35] Ibid., p. 1334.

[36] Ibid., pp. 1346–1351.

[37] Ibid., pp. 1345–1346.

[38] Ibid., p. 1351.

CHAPTER XIII

Early Growth of Naval Communications

THE UNITED STATES NAVAL RADIO SITUATION IN 1908

Radio equipment had been installed in all naval surface vessels and most of the low-powered shore radio stations had been in operation for 4 years by mid-summer 1907. Accustomed as we are, in the mid-20th century, to rapid technological development, it would be expected that use of radio would have increased quickly as a means of intrafleet communication and also as a means of controlling fleet operations from the seat of government. Unfortunately, this did not occur. Increase in knowledge of the science was extremely limited and the lack of improvement of apparatus suffered correspondingly. There was little quantitative knowledge of the requirements, and equipment was assembled by the trial-and-error method. Frequency was controlled by constructing antennas with a natural period approximating that to be used. No single firm held, or could legally use, all the worthwhile patents to improvements. Once a patent was obtained, the patentee or his asignee held it tightly and refused to license others in its use because of the desire to eliminate competition and establish a monopoly.

Along our continental coastlines the Navy had erected and was operating several chains of radio stations each of which could relay a message from one station to another for the full length of each coast. On the Atlantic seaboard a message could be sent, under favorable conditions, as far as the Canal Zone. There were no means of connecting the east- and west-coast chains except by landlines. Installations had been completed in our insular possessions but, with the exception of those in the Caribbean, the only interconnections between them and the continental stations were the cables. Generally speaking, there was some, but not sufficent, supervision over these stations. Since naval installations and many others all operated in a band close about 750 kc., there was much unintentional interference between adjacent naval sations and considerable intentional and unintentional interference between naval, commercial, and amateur stations. No attempt was made to use several different frequencies, and if such had been made it would have been useless, for the wide-band transmissions of the old spark apparatus emitted at least one additional wide-band frequency almost equal in intensity to the primary and their combined emissions covered most of the spectrum in use. The stations with high power and large antenna systems were somewhat like the "bull in the china shop." Their transmissions carried through to their limited range but in doing so they "broke up" all others in the vicinity. No efforts were made to limit the power used to that required for the distance involved.

Following Evans' limited attempts to develop radio for strategic usage, no further training had been carried on for this purpose. No endeavor had been made to develop it as a means of tactical communications. The original installations, with poor internal communications with the bridge, did not readily lend themselves to such purpose. Seafaring men, accustomed to fighting the elements and navigating uncharted waters wherein often floated unknown obstructions, have by custom, tradition, and training become a conservative group under peacetime conditions. They are slow to accept innovations. Commanders were familiar with maneuvering their ships in close formation by flag-hoist signals. They themselves could readily see, during periods of good visibility, when all their ships had received and understood the orders for the evolutions. They were not prone to use a signaling method they could not see, nor understand, and one which they certainly distrusted. Without considerable training and development of standard operating procedures during periods of good visibility, this strange, chattering device was of no value during poor visibility. Moreover, most officers sincerely believed that the large topside antennas would quickly be damaged in battle, either by blasts of our own gunfire or by enemy action, and that it was nothing short of folly to depend upon such a system. Within the fleet no central authority exercised control over radio use nor specified periods of maintenance. An installation could be secured at the will of the commanding officer or operator without knowledge of a unit commander. This did not add to its reliability as a means of tactical communications. Without the exercise of central control it became more and more unreliable and disdained, and rapidly became merely a seaward extension of the telegraph system. Even for this purpose it was extremely limited in range. The range was often further reduced by some commanders who secured their equipments as soon as they were at sea in order to eliminate what they considered an undesirable shore contact. Under these conditions shipboard radio quickly developed into a toy for the radio operators and a means for passing personal and often frivolous messages ashore. These conditions could only be corrected by positive action on the part of a fleet commander who, in turn, lacked a technically qualified staff to assist in performing this function.

From this analysis it is readily apparent that many requirements had to be met before radio could be adopted as a satisfactory mode of intrafleet tactical and strategical communications. Improved and reliable narrow-band transmitting equipment, both low and high powered, capable of being quickly shifted to any of several different frequencies, was necessary, but there appeared little likelihood of such becoming available. In view of this, the most immediate need was a central authority capable of educating officers in the proper use of radio and of establishing a controlled operating organization from which a disciplined use of the medium might be evolved. Next in importance was the establishment of a scientific group to study and evolve the theories underlying radio and radio-wave propagation in order to meet the requirements for improved apparatus and its more knowledgeable use. Another very important requirement was for a system which could be adapted to tactical usage within the fleet, utilizing a smaller antenna and without creating interference to other radio circuits and capable of being located where it could be in instant and reliable communication with the commanders of ships, units, or fleets. These requirements were all well understood by the personnel of the Radio Division of the Bureau of Equipment.

BUREAU OF EQUIPMENT RADIO PLANNING

Late in 1906 Lt. Comdr. Cleland Davis,[1] USN, became the head of the Radio Division and continued in this post for better than 3 frustrating years. His predecessors, Hudgins, Jayne, and Robison, had built up the existent system. Requirements for new equipments of existent types were limited

[1] Davis was born in, and appointed a naval cadet from, Kentucky. He graduated from the U.S. Naval Academy in 1890. On 22 May 1916 he retired as a commander but was subsequently appointed a captain on the retired list. He died 20 Oct. 1948.

to those necessary for fitting newly constructed naval vessels, replacement of damaged equipments, or for a small increase in the number of shore stations. Davis was in a position to devote much of his time to the improvement of equipment and in planning to eliminate uncovered ocean areas. Both he and his assistant, Lt. George C. Sweet,[2] USN, possessed considerable vision and early in their tour of duty evolved a plan for a system of high-powered stations which would cover all necessary ocean areas and which would be intercommunicable and supported by the existent relatively low-powered shore stations as a secondary system. Their long-range planning was so excellent that its results remain apparent in the present U.S. Naval Radio System. The only major changes are the result of the increased ranges, obtainable by utilization of higher frequencies, improved apparatus and the necessities created by changing world conditions and modes of defense. Realizing the antagonism of many officers and the indifference of most of the remainder, Davis made no effort to force an organization upon the fleet. He contented himself with the planning for the future and with the endeavor to improve equipment to the end that this mode of communication might be more readily accepted. Through his entire tour of duty he was constantly berated by most of the firms which were unsuccessful in obtaining naval contracts and was beset by threats of infringement suits as well. During the period of his tenure the Senate refused to ratify the Berlin convention and the several Congresses would not enact legislation controlling the use of radio. None of his planning bore fruit during this period and several of his efforts were failures, some due to too hasty action on his part. It is probable that he welcomed his relief, happy to leave such a thankless and unsatisfying billet.

THE RADIOTELEPHONE FAILURE

One of the first mistakes of the Davis regime was that of becoming too quickly convinced of the capabilities and promises of the radiotelephone equipment developed by De Forest in the summer of 1907. This apparatus appeared to be the answer to the requirement for fleet tactical radio equipments. Two sets were purchased and installed in the U.S.S. *Connecticut* and U.S.S. *Virginia* and hasty and incomplete, but fairly successful, tests of this apparatus were conducted in September of that year.[3] The Bureau of Equipment, departing from its usual conservative policy, ordered 26 sets of the equipment for installation in ships scheduled to depart Hampton Roads, Va., on 26 December, for the famed "Around the World Cruise." Only 40 days were allowed for the manufacture of this equipment.[4] Under ordinary circumstances De Forest equipment was noted for its lack of engineering design and perfection and under such hurried procurement the equipment delivered was far below this normal poor quality. A news item of December 1907 contains a statement by Evans that the sets were being installed at his insistance.[5] Subsequent events indicate that this statement was obtained and provided newspapers by the publicity-minded De Forest, who saw the possibility of enhancing his equipment and stock sales by publicizing the Navy contract in this manner.

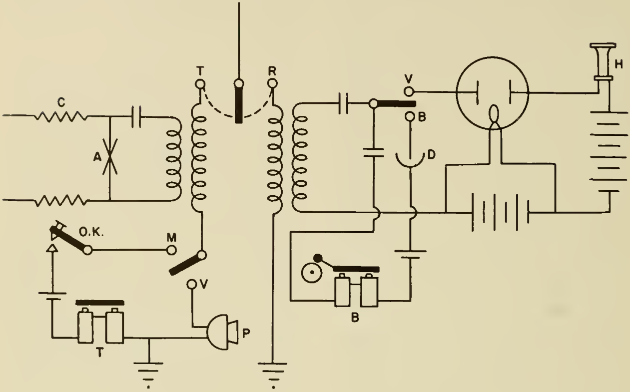
[2] Sweet was born in, and appointed a naval cadet from, New York. He graduated from the U.S. Naval Academy in 1898 and was later designated a naval constructor. During his career he was expressly interested in both aviation and radio. He was retired as a commander on 3 Mar. 1915 because of a physical disability. He returned to active duty during World War I and was decorated by the French Government for services rendered that country in construction of Lafayette, Radio Station. He died 6 Aug. 1953.

[3] Lee De Forest, "Father of Radio" (Wilcox & Follett Co., Chicago, 1950), p. 232.

[4] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., SRM 100–10.

[5] Globe and Commercial Advertiser, New York, 3 Dec. 1907.

Schematic Diagram of DeForest Radio Telephone Sets Purchased By The United States Navy, 1907



A – ARC
C – CHOKE COILS
T – TIKKER
M/V – CALL-CODE/VOICE SWITCH
OK – OPERATOR'S MORSE KEY
P – MICROPHONE
T/R – ANTENNA TRANSMIT-RECEIVE SWITCH
V/B – VOICE/CODE-CALL SWITCH
H – TELEPHONE RECEIVER
D – CRYSTAL DETECTOR FOR CALL CIRCUIT
B – CALL BUZZER

Reconstructed from Information Contained in Robison's Manual of Wireless Telegraphy, 1911 and Other Official Navy Records

Figure 13–1.

When delivered, the equipments were hastily installed. Those for many of the ships were shipped to Rio de Janeiro, Brazil, where they were installed by the radio personnel of the individual ships. No instruction in the operation of this apparatus had been provided the watch officers who were supposed to utilize it on the bridge in a manner somewhat similar but more complicated than the ordinary telephone, nor had any effort been made to encourage their acceptance of it. It had been designed to use approximately the same frequency as that used by other shipboard radio equipment; therefore, it could not be used simultaneously with that equipment.[6] At the time, this was not a serious problem because the fleet was, for the greater part of the time, out of range of communications with shore stations.

Bean, one of the chief petty officers who had gone to Europe with Hudgins to study radio apparatus and who was closely associated with the development of radio in the Navy, recalled that the U.S.S. *Ohio* was detached from the fleet during part of the cruise and, being alone, was allowed to "experiment" with the telephone, but the rest of the fleet was not, for as soon as they left port "old Admiral Evans ordered the sets dismantled and the antennas taken down. This was because there was too much playing with the new toy; also, too much interference with the regular spark operation." [7] This does not support the contention that Evans insisted upon the installations of this apparatus.

H. J. Meneratti, who later retired as a captain, USN, was a chief electrician's mate aboard the *Ohio*. In a recent discussion of the radiotelephone, he conceded that it was tricky. It was difficult to keep the arc, made up of carbon and copper electrodes which were contained within a chamber filled with hydrogen-carbon gas, in adjustment. By 12 January 1908 they had managed to keep the *Ohio's* set in operation for several hours at a time, during which periods they broadcast music from the ship's band. As time went on they were able to increase the operable intervals. When they arrived in San Francisco a phonograph and a collection of records were obtained and, throughout the remainder of the cruise and during their visits to various ports, they broadcast music, much to the amazement of those who chanced to hear it.[8]

However, the equipment was never used for the purpose for which it was installed. No singular authority pressed it into service for tactical purposes or endeavored to develop a plan for its usage. De Forest had just developed the three-element tube and he had little knowledge of why or how it operated and he was always prone to place equipment under manufacture prior to obtaining a satisfactory engineered design. This, coupled with the 40 days allowed for the manufacture of 26 sets, most parts of which were made by hand, was sufficient to insure delivery of unreliable equipment. Added to this, the sets were placed on ships which would be distant from their home ports for months without the necessary engineering maintenance and supply of spare parts. In view of these facts, it is doubtful that all equipments could have been kept constantly operable, and certainly this lack of reliability largely nullified its use. Had the Bureau of Equipment followed the orderly procedure of procuring a few sets and of testing these exhaustively, while simultaneously training both officers and men in their usage, it is probable that the apparatus could have been satisfactorily redesigned and engineered to produce a radiotelephone set that would have proved reliable. The failure of this project did much to increase the convictions of many naval personnel that radio could not be developed into a reliable means of intrafleet communications. Upon the return of

[6] This was an error on the part of the Radio Division in that they should have specified a different frequency for this apparatus.

[7] William H. Medd, Gunner, USN (retired) "Pioneering in Radio" (private issue, 1938), p. 17.

[8] Substance of a statement made by Meneratti to the author on 16 Dec. 1955.

the fleet to the United States, the equipment was turned into store at the Brooklyn Navy Yard and from that time until 1917 the Navy was without radiotelephone installations.[9]

ESTABLISHMENT AND EARLY ACCOMPLISHMENTS OF THE NAVAL RADIO RESEARCH LABORATORY

The radiotelephone fiasco helped to point out the necessity of the Navy's having its own radio scientific and engineering personnel to prevent similar blunders and to provide continuity of personnel. A decision was reached to establish a research laboratory for the investigation of the various problems involved in development and engineering of naval radio equipment. Discussion of this with Dr. S. W. Stratton, Director of the Bureau of Standards, brought forth the offer of quarters for the proposed laboratory, together with a portion of the required apparatus and the use of the general equipment of the Bureau.[10] Dr. L. W. Austin, noted physicist and an international authority on radio, was then conducting tests under the auspices of the Bureau of Standards. He was transferred to the Navy Department to head the newly established U.S. Navy Radio Laboratory. Arrangements for beginning the research activities were worked out during the summer of 1908.

In his recommendations, Austin separated the work of the Laboratory into two divisions. The first included the experiments to be conducted in the Laboratory. The second consisted of experiments to be planned and supervised by the Laboratory but carried out at operating stations.[11] As planned, the initial task of the Laboratory was to produce primary high-frequency inductance and condenser standards. Tests in connection with the sensitiveness of different types of receivers with their telephone headsets and other ancillary apparatus under varying conditions of damping and frequency were to be made at the laboratory where they could be conducted much more accurately and expeditiously. Additionally assigned Laboratory functions were a study to reduce the damping losses in the transmitting circuits; a study of dielectric losses in various glass and oil condensers; investigations to determine the best form of spark gap; studies to determine the best ratios of inductance and capacity for different frequencies; the most efficient coupling to be used between the receiving circuits; a determination of the best method of connecting the receiver to obtain maximum efficiency in order that a receiver giving maximum signal strength with sharpest tuning might be obtained; studies in connection with the production of radio waves by the arc transmitter and the high-frequency alternator; and training personnel in the proper methods of testing the efficiency of equipment at the operating stations.[12]

The tasks assigned for accomplishment at shore radio stations included a study of the efficiency of different types of transmitting devices such as the arc, the high-frequency alternator, and various types of damped spark apparatus; a determination of the best forms of antennas, both transmitting and receiving; quantitative determination of ground resistances under various conditions; a study of the action of waves between transmitter and receiver, including a quantitative study of atmospheric absorption; and the study of methods of eliminating atmospheric disturbances.[13]

To provide advice relative to radio engineering and to give a desirable continuity of effort, which could not be supplied by

[9] Ibid.

[10] L. W. Austin, "The Work of the U.S. Naval Radiotelegraphic Laboratory," Journal of the American Society of Naval Engineers, vol. 24, February 1912, p. 122.

[11] Letter, dated 15 June 1908, Dr. Louis W. Austin to Lieutenant Commander Davis, USN, Bureau of Equipment, files, Bureau of Equipment, National Archives, Washington, D.C.

[12] Austin, op. cit., pp. 124–141.

[13] Ibid.

officers because of the necessity for their rotation between sea and shore billets, a small corps of civilian radio experts was established at this time. After qualifying by technical examination, Mr. George H. Clark, who since his graduation from the Massachusetts Institute of Technology in 1903 had been in the employ of the Stone Telephone & Telegraph Co., was given the first appointment to this corps.[14] His original title was "subinspector of radio." During the years he was, as he termed himself, "a Government pauper," he contributed greatly to the improvement of equipment and gave valuable assistance in the studies on wave propagation and other research projects.[15]

Dr. Austin's sole assistant during the first year was Clark, who aided him whenever he could be spared from his other duty as an adviser to the head of the Radio Division. Later, a number of chief electrician's mates were assigned, either as assistants or for training, and some of these, despite lack of university education, showed considerable aptitude.[16]

The first investigative work of the Laboratory was begun in September 1908. Prior to beginning the work as planned, Austin was directed to conduct tests of the Poulsen arc. Two sets of this equipment had been purchased in Denmark in 1907 on the recommendation of Rear Admiral Manney,[17] who had witnessed this apparatus in operation prior to returning to the United States after the conclusion of the Berlin Conference. The transmitter produced fairly sharp, undamped waves by an arc formed in alcohol vapor, the current being supplied by a 500-volt direct-current generator. Fair results were obtained over distances up to 40 miles, but it was concluded that the equipment required more skillful attention than would be readily available and that it was too bulky for shipboard installation. These conclusions were unfortunate, for this type of equipment remained neglected for the next 4 years. It was an earlier version of the transmitter which was to become and remain the Navy's standard for many years before being supplanted by electronic equipment.

Following the completion of the tests of the Poulsen equipment, the Laboratory began the development of methods for the exact measurement of circuit variables. Some methods for accomplishing this were adopted from European practices. Among these devices were ones for determination of (1) current flow in receiving antennas, when the current was too weak to be measured quantitatively by existing methods; (2) the sensitiveness of telephone headsets and detectors; (3) the comparative efficiency of receiving sets; and (4) antenna resistances. A systematic study was made of current distribution in coupled receiving circuits under varying degrees of damping of transmitted waves. This work indicated the necessity for using variable coupling to obtain maximum signal intensity with satisfactory sharpness of tuning.[18]

UTILIZATION OF NEWLY DEVELOPED APPARATUS

During this time advantage was taken of the newly developed IP76, crystal-detector, receivers developed by Pickard of the Wireless Specialty Apparatus Co. These were

[14] Letter, dated 4 Aug. 1908, Naval Examining Board to Secretary of the Navy, files, Bureau of Equipment, National Archives, Washington, D.C.

[15] "Radioana," op. cit., CWC 4–3481A. Clark resigned his position with the Navy in 1920 to accept employment with the Radio Corp. of America. He eventually became the historian of that organization and collected volumes of information on early radio matters which eventually were reposited in the Engineering Library of the Massachusetts Institute of Technology, Cambridge, Mass. Electronics historians are indebted to him for this collection of "Radioana."

[16] Austin, op. cit., p. 123.

[17] Letter, dated 23 Jan. 1907, H. N. Manney to the Chief of the Bureau of Equipment; cable, 27 Mar. 1907, from the Chief of the Bureau of Equipment to F. M. Barber, files, Bureau of Equipment, National Archives, Washington, D.C.

[18] Austin, op. cit., pp. 124–125.

recommended by the Laboratory and large quantities were purchased to replace the obsolescent Slaby-Arco, De Forest, Shoemaker, Massie, and Stone equipments of earlier purchase. The IP76 was a simple two-circuit receiver, with so-called untuned secondaries (secondary coils of fine, closely wound wire, whose natural period could be roughly approximated to that of the incoming signal by selection of turns). It was improved within a few months by B. F. Miessner, a naval radio electrician's mate stationed at the Washington Navy Yard, by the addition of the popularly named "cat whisker," a fine metal point maintained in light contact with the crystal. These "Navy standard" receivers were installed in practically all ship and shore stations.

Almost from the beginning of radio, engineers realized the advantages of undamped waves, especially for telephony, but the problems of generating and receiving them were not immediately surmountable. The arc transmitter which generated continuous waves was introduced by Poulsen in 1903, but it was many years before it was simplified sufficiently to make it generally usable. The three-element tube as a generator of undamped oscillations did not become available until after 1912. Unable to devise satisfactory continuous-wave transmitters, radio engineers had constantly sought to devise a means of reducing the damping of the spark transmitter's oscillations. The first of these transmitters had produced a 60-cycle, or less, output. This was gradually increased, as in the case of the Navy modification of the early Slaby-Arco transmitters, by increasing the number of segments in the mercury interrupter, again and again, until finally they produced a "sweeter note" at about 500 cycles. Next, the spark gap was enclosed and operated under pressure, and this was followed by the quenched gaps of Chafee and Wein and the synchronous rotary gap employed by Fessenden. These made it possible to provide an initial impulse to the antenna, after which it was disconnected for an infinitesimal period of time to permit it to oscillate at its natural period and thus reduce the damping. Fessenden had been granted U.S. Patent No. 706,740 on the heterodyne method of reception in 1902.[19] The early use of this method was cumbersome, and the idea laid almost dormant until the National Electric Signaling Co. was forced to use it as a method of reception in an endeavor to fulfill their Navy contract for the 100-kw. synchronous rotary spark transmitter. This proved to be the most satisfactory method for the reception of continuous waves.

The only other means available for the reception of continuous waves was Poulsen's "tikker" or the variations of this device developed by Goldschmidt of Germany and by Austin of the Naval Radio Research Laboratory. The Poulsen device utilized a mechanical vibrator in the secondary circuit of the antenna coupler in series with a telephone headset and a condenser connected in parallel. The condenser was charged and discharged at a rapid rate by the vibrator rapidly opening and closing the circuit. The condenser charging current was controlled by the antenna oscillations, and this produced groups of audible sounds corresponding to the transmissions of the station being received.

PORTABLE SETS

Following the failure of the radiotelephone, there remained a primary requirement for a small portable set for fitting on ship's bridges for tactical usage. Secondarily, such equipment could be used by the landing force of a ship or for fitting in small boats. The National Electric Supply Co. of Washington, under the supervision of the personnel of the Radio Division, designed and built such a set, and the Bureau contracted for a small number for service tests. These were designed to provide a

[19] Fessenden was granted two additional patents on the heterodyne method in 1913.

light, easily adjusted equipment which, at the time a ship was "cleared for action," could be set up in a sheltered position and connected to a small antenna to provide intrafleet communications during battle with some degree of freedom from interference by the enemy. It was transportable and was contained in a single case approximately the size of a dress suitcase. Late in 1908, several of these sets were delivered to the Atlantic Fleet for service testing conducted under the supervision of the fleet signal officer, Lt. W. R. Wurtsbaugh, USN.[20]

Before conducting the experiments, Wurtsbaugh made a thorough anaylsis of the problem to determine requirements and to study unknown factors. For long-distance communications the location of the antenna in an exposed and lofty position was necessary, as was, at that time, the location of a radio room above deck. For short distances involved during an action it would be of great advantage to shift to a battle radio station protected from enemy fire. Considering these factors, it was recommended that a complete battle radio apparatus be installed below the protective deck in two of the vessels of the fleet, preferably two flagships, to conduct experiments using a secondary antenna, which could be rigged on either side of the ship and protected by the armor belt. It was recommended that this proposed battle radio room be near the central station and have voice tube and telephone connections with the conning tower. In his letter Wurtsbaugh stated that the importance of a well-protected battle radio room could not be underestimated in view of the vulnerability and slowness of flag signals under battle conditions. He considered that the matter of interference could be overcome by the use of simple codes in which a signal is given by repeating a single letter or two letters until understood by all the ships of a fleet. The analysis presented two pertinent questions: (1) Can an antenna be so located as to be reasonably safe from danger by gunfire of the enemy? and (2) Will the firing of the ship's battery interfere with the receiving of messages?[21]

These recommendations were approved, and experiments were conducted for the purpose of providing answers to these questions. The U.S.S. *Connecticut* and U.S.S. *Virginia* were fitted, by means of outriggers, with short single-wire antennas, about 20 feet in length, along the side of each ship which would be considered unengaged during a forthcoming battle practice. These antennas were entirely below the armor belt and reasonably safe from damage during action. Because of the reduced lengths of these antennas they did not prove completely satisfactory, but messages were exchanged between the two ships at distances up to 5 miles. During the battle practice a portable receiving set was installed below the protective deck and free from the noises incident to firing. Utilizing these installations, the *Virginia* transmitted messages which were received by the *Connecticut* while the latter was firing. Since it appeared that an antenna of greater length was desirable, the *Connecticut* rigged a two-wire antenna, of the same length as the regular antenna, just clear of the ship's side, beginning at the height of the lower bridge. After successfully receiving at a distance of 15 to 20 miles, it was lowered by successive stages until it was just clear of the water and of the ship's side. The results demonstrated that, for fleet work within a radius of 15 or 20 miles, a fully protected antenna similar to this could be used satisfactorily.[22]

Later, portable sets were delivered to the Special Service Squadron for additional tests under tropical conditions. Sweet, having been relieved of his duties in the Radio Division, was then serving in this unit and he was assigned the responsibility of conducting the tests. His report, forwarded by

[20] Letter, dated 7 Jan. 1909, W. R. Wurtsbaugh to the Commander in Chief, U.S. Atlantic Fleet, files, Bureau of Equipment, National Archives, Washington, D.C.

[21] Ibid.

[22] Ibid.

the Commander, Special Service Squadron, to the Navy Department in August 1910, was comprehensive and indicated that the equipment had been most thoroughly tested.

In commenting upon and making recommendations for the improvement of the transmitter, he noted that the secondary and discharger circuits performed their functions satisfactorily and that the singing spark was, without doubt, the best form of that type of equipment yet supplied. He recommended that two gaps be supplied with each equipment in order that one would always be available while the other was being cleaned or overhauled; that the Leyden jar condensers be replaced by plate condensers made up of tinfoil and paraffined paper; that the induction coils should be capable of stepping up the voltage to 5,000 volts and of maintaining their full capacity for at least 24 hours; and that the primary of the coil should be better proportioned for a frequency of 500 cycles. Continuing, he commented that the arrangement of obtaining the 500-cycle current from the brushes of the primary coil and having the operating key in series with the field of the alternator proved successful, but it made little difference in the speed regulation whether that method was used or one of keeping the field constant and placing the key in series with the brushes. In view of these factors, he recommended the use of the latter method because the delivered voltage was more constant. He also recommended inclusion of a means of providing three constant alternator speeds of 300, 400, and 500 cycles.[23]

In commenting on the design and construction of the receiver, Sweet mentioned that the sealed carborundum detector was unsatisfactory because the steel burned at the contact; that the tuning coil should be improved by constructing it similar to the one in the transmitter in order to provide selective secondary tuned circuits; and that appropriate condenser capacity should be provided so that frequency could be shifted by a single action.[24]

The apparatus was tested using various types of antennas from one of about 705 kc. natural frequency down to a single insulated No. 20 copper wire hoisted half way to a signal yard by a halyard. Experimentally, it was determined the best battle antenna for these low-voltage sets was a single flexible insulated cable suspended from a height of about 80 feet. Such an antenna had the advantage that, if shot away, it could be easily and quickly replaced and, additionally, that it helped to eliminate interference from stations using antennae of longer lengths.[25]

The report recommended placement of the equipment in the conning tower where it would be afforded adequate protection and where the rubber-insulated antenna could be led out a sight slit and hoisted to the yardarm. In this location the operator would have immediate and positive communications with the commanding officer.[26]

The report closed with the recommendation that these improvements be incorporated and the equipment again be service tested. It further recommended that, when proven satisfactory, several sets should be provided each ship likely to engage in battle.[27]

The improvements suggested were incorporated in the specifications for portable equipment and the new apparatus proved to be a rugged, capable equipment. It was the forerunner of the auxiliary or battle radio set, landing force and small-boat equiment and, what is more important, it stimulated study and experimentation which led to the production of more rugged and compact equipment and also pointed the way towards the eventual equipping of aircraft and submarines.[28]

[22] Letter, dated 2 Aug. 1910, G. C. Sweet to the Commander, 5th Division, U.S. Atlantic Fleet, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[24] Ibid.

[25] Ibid.

[26] Ibid.

[27] Ibid.

[28] Hooper, op. cit., pp. 502—503.

INITIAL TESTS OF THE FESSENDEN 100 KW. SYNCHRONOUS ROTARY SPARK TRANSMITTER

Although the plans for a chain of high-powered stations, capable of intercommunicating with each other and of delivering messages to ships regardless of where they might be operating had been completed, no equipment had been found which would meet the requirements. Prior to going before Congress with a request for the necessary appropriation, it was necessary that satisfactory equipment be available. It was at this time that Firth offered the Fessenden equipment with satisfactory guarantees of performance. As previously related, this equipment was purchased, subject to its performance meeting the required stipulations. This purchase also resulted in an averment of collusion by the De Forest interests.

The contract called for conducting experiments with the transmitter while it was still located at the National Electric Signaling Co. station at Brant Rock, Mass. Because of the power available there, it could only be operated at 60 percent of its rated capacity with the antenna supported by a single 400-foot tower. Hence, no final conclusions were reached at Brant Rock. The final acceptance of the equipment was deferred awaiting the construction of the buildings, towers, and antenna at Washington. In the meantime, in order to gain information concerning the apparatus, experiments were conducted utilizing the U.S.S. *Salem* and *Birmingham*, each of which was fitted with a Fessenden 10-kw. transmitter of the same type as the 100-kw. During these experiments, conducted during December 1909, the *Salem* and *Birmingham* were each stationed 1,000 miles from Brant Rock and the same distance from each other. There was a severe storm during most of the period of this experiment and the results were not satisfactory.[29] Following these experiments the two cruisers put into the Norfolk Navy Yard to have new topmasts fitted to increase the antenna height to 156 feet and span to 175 feet.[30]

Further experiments were conducted during July 1910, at which time the cruisers were able to maintain communication with each other for a distance of 600 miles by day. The U.S.S. *Birmingham* received messages from Brant Rock during daylight when distant 900 miles, and on one occasion maintained communication with that station during darkness when distant 2,186 miles and copied press at night at a distance of 2,271 miles. During these experiments it was determined that the 10-kw. transmitters were more powerful than required for loading any antenna with which the cruisers could be fitted.[31] A similar 25-kw. transmitter, which had been installed in the U.S.S. *Connecticut,* had also been determined to be too powerful and was removed for later installation at Key West, Fla. The experiments at this time indicated that the 100-kw. transmitter, even when properly installed, would not meet the contract requirements. However, it would be superior to other available equipment and would suffice for long-distance intercommunications between shore stations because of the availability of larger and more directional antennas.

One of the most important results of the Brant Rock-cruiser tests was the determination of the mathematical law governing the strengths of received signals at specific distances. From the data thus obtained, Dr. Austin, assisted by Dr. Louis Cohen, of the National Electric Signaling Co., empirically established the Austin-Cohen formula. So thorough was this work that, with minor variations, correcting for solar activity, time of day, and frequency attenuation, it is still used for the determination of field strength at long distances.[32]

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[29] Electrical World, (McGraw-Hill Publishing Co., New York.), vol. LV, no. 1, 6 Jan. 1910, p. 27.

[30] Ibid., 31 March 1910, p. 807, vol. LV, no. 13.

[31] Letter, dated 2 Aug. 1910, W. B. Fletcher to the Secretary of the Navy, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[32] S. C. Hooper, "Navy History—Radio, Radar, Sonar," transcript of recordings, pp. 26–27, Office of Naval History, Washington, D.C.

THE MARCONI INTERESTS AGAIN INVADE

The Marconi Wireless Telegraph Co. of America had made no protestation when the contract for the Fessenden transmitter was made, but after the tests in July 1910 they addressed a letter to the Secretary of the Navy requesting information concerning the carrying out of the contract with National Electric Signaling Co., stating that they had been informed that both the secrecy and the distance tests were unsatisfactory. In case the Department contemplated erecting a tower in Washington for the purpose of communicating distances up to 3,000 miles, the company protested against the award of any new contract without the Marconi Co. being given an opportunity to prove its ability to meet the specifications.[33] The Department replied that the proposed Washington towers were necessary to carry out the contract with the National Electric Signaling Co., the height of the Brant Rock tower and the power available there being insufficient to determine satisfactorily whether or not the contractor could fully carry out the provisions of his contract.[34] Replying, the Marconi Co. stated that the conditions of the contract with the National Electric Signaling Co. appeared totally different to those required on the schedule on which the Marconi Co. had bid; that its tender would have been on a totally different basis and bids for the radio equipment of the station would have been submitted which they believed would have been satisfactory to the Department; and that the 190-day time limit set for the completion of the station had long been passed. With the view of obtaining the contract for apparatus for long-distance communication in the contemplated station in Washington, the company renewed its offer to permit the Government to use its own high-powered stations already erected in Nova Scotia and Ireland to make tests. If such arrangements could not be made, they believed that the schedule should be recalled and bids for the installation of radio apparatus in the Washington station should be readvertised for general competition.[35] To this the Department replied that the contract with the National Electric Signaling Co. was made on the basis of its bid which complied with the specifications and requirements prescribed by the Department; that the change in the contract whereby the tower called for was to be erected by the Government instead of by the contractor was made in view of the circumstances occurring subsequent to the award of the contract, which in the Department's judgment required such modification in the interest of the Government; that the contracting company undertook in good faith to supply the Department with apparatus possessing the characteristics and power called for in the specifications issued to prospective bidders; that in certain respects the delay in the completion of the station had not been without advantage to the Government; and that it was not considered that the public interests required the making of other arrangements or cancellation of the contract.[36]

RADIO (ARLINGTON), VIRGINIA, SELECTED AS SITE OF HIGH-POWERED STATION

Action was instituted to determine a location for the new radio station in the vicini-

[33] Letter, dated 29 July 1910, Marconi Wireless Telegraph Co. of America to the Secretary of the Navy, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[34] Letter, dated 1 Aug. 1910, The Secretary of the Navy to the Marconi Wireless Telegraph Co. of America, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[35] Letter, dated 12 Aug. 1910, Marconi Wireless Telegraph Co. of America to the Secretary of the Navy, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[36] Letter, dated 10 Oct. 1910, the Secretary of the Navy to the Marconi Wireless Telegraph Co. of America, files, Bureau of Steam Engineering Archives, Washington, D.C.

ty of Washington. After considering sites at the Naval Observatory, the Old Soldiers' Home, and Fort Myer, the latter was chosen, and the land was transferred from the War Department to the Navy.[37]

NAVY DEPARTMENT REORGANIZATION AND THE NAVAL RADIO SYSTEM

Early in 1910 plans were being made to reorganize the Navy Department in accordance with congressional legislation. The Bureau of Equipment was to be abolished and its functions were to be divided among materiel bureaus and the naval operations agency, the Bureau of Navigation. At this time the Chief of the Bureau of Equipment informed the Secretary of the Navy that were were recent definite improvements in radio equipment and that a point in its development had been reached where it would not become obsolete and require replacement before giving adequate service for the money expended.[38] He further stated that it was incumbent upon the Department to modernize the apparatus on board all important ships and at all shore stations and that the necessary steps to effect this were being taken. To ensure the installation of proper improved apparatus in all the stations, both ship and shore, it was requested that the Bureau be informed of the strategic and tactical requirements and the ranges necessary for each shore station and for the several types of vessels. It was suggested that some new shore stations be established and that a few of the existent ones might be closed. Guidance in other matters was requested concerning the effect of the changes on the administration and operation of the naval radio system, with the bureau suggesting the establishment of an operating and administrative organization district and separate from the technical one. A decision was requested as to whether it would be advisable to employ civilian operators for shore stations instead of enlisted men.[39]

This letter was referred to the Navy General Board which, in its endorsement on the basic letter, observed that the Board believed that the general administration of radio shore stations maintained by the Navy and the operational control of radio communications should be a function of the Division of Operations, Bureau of Navigation, with the material and personnel functions remaining under the cognizance of the appropriate bureaus. The Board advised that, since the coast radio stations and all radio communications to and from them must be under naval control in time of war, it did not consider it desirable to employ civilian operators for these stations at any time. The ranges of the stations should, in all cases, only be limited by the capabilities of the apparatus. The Division of Operations should decide the number and location of shore stations.[40]

In his endorsement, the Acting Secretary of the Navy stated that the Division of Operations would assume the operational control of naval radio communications and would decide all questions concerning the establishment, abandonment, location, and relative importance of radio stations and the tactical requirements of fleet units. He further directed that the Bureau of Navigation would fix their complements and issue necessary regulations for their control, and that the new Bureau of Steam Engi-

[37] Letter, dated 14 Sept. 1910, Bureau of Steam Engineering to the Secretary of the Navy; Memorandum, dated 5 Oct. 1910, S. S. Robison, USN, to the Chief of the Bureau of Steam Engineering, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[38] This statement is difficult to understand. The only improvements were utilization of quenched gaps and Wireless Specialty Apparatus Co. receivers.

[39] Letter, dated 6 April 1910, Chief of the Bureau of Equipment to the Secretary of the Navy, files, Bureau of Steam Engineering, 1910, National Archives, Washington, D.C.

[40] Ibid., first endorsement.

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neering would be responsible for providing stations and equipments and for maintaining them.[41]

The new organization became effective on 1 July 1910, with Rear Admiral Hutch I. Cone,[42] USN, as Chief of the Bureau of Steam Engineering, and Lt. Comdr. D. W. Todd,[43] USN, as Head of the Radio Division of that newly established Bureau. Unfortunately, the Chief of the Bureau of Navigation did not deem it necessary to establish a radio section in his Division of Operations so no central authority was established to direct radio operations or to evolve policies. Forced by this default, the Bureau of Steam Engineering continued to handle radio matters much as it had in the past.

Throughout his tour of duty, which ended in 1913 when he was relieved by Lt. Comdr. A. J. Hepburn,[44] USN, Todd was fully occupied with the tasks of obtaining the passage of legislature for Federal control of radio and in the preparation for and of being a delegate to the Third International Radio Conference.[45] Since the resolutions of the problems concerned with these activities, all of which reached fruition under his guidance, required the exercise of maximum tact and diplomacy but left little time to attend to the details of material improvement, he accepted the planning of his predecessor and left to his assistants the work of implementing such plans.

[41] Ibid., third endorsement.

[42] Cone was born in, and appointed a naval cadet from, Florida. He graduated from the Naval Academy in 1894. He continued to serve as Chief of the Bureau of Steam Engineering through most of World War I. For services during that war he received the Distinguished Service Medal and the French Legion of Honor. He retired on 11 July 1922 and died on 12 Feb. 1941.

[43] Todd was born in, and appointed a naval cadet from, California. He graduated from the Naval Academy in 1895. He was Director, Naval Communications during World War I and for his services he received the Navy Cross and the French Legion of Honor. He retired 31 Mar. 1930 as a captain and died 21 Aug. 1946.

[44] Hepburn was born in, and appointed a naval cadet from, Pennsylvania. For World War I service he received the Distinguished Service Medal. He was Commander in Chief, U.S. Fleet 1937–38. Following this he was Chief of Naval Operations until his retirement on 1 Nov. 1941.

[45] Supra, ch. XII.

THE NAVAL RADIO SYSTEM in ALASKA

The Army Signal Corps was early assigned the responsibility for interior telephone and telegraph facilities in Alaska and the Aleutians. Radio communications between these areas and continental United States was, by the Roosevelt edict of 1904 and in the absence of commercial facilities, the responsibility of the Navy. Commercial and Government business necessitated the establishment of radio stations to provide rapid communication between these areas and Seattle, Wash.[46] In the spring of 1911, material for three stations was embarked in the U.S.S. *Buffalo* with a construction force from the Mare Island Navy Yard.[47] Temporary stations were set up at Kodiak, Dutch Harbor, and St. Paul. The station at Kodiak was totally destroyed by fire when struck by lightning on 8 June 1912.[48]

Another expedition departed Mare Island on 20 May 1912 under the Command of Lt. E. H. Dodd, USN, assisted by Expert Radio Aid George E. Hanscom, to make permanent installations. Under most trying and difficult weather conditions, with winds

[46] Letter, dated 30 Jan. 1911, the Secretary of the Navy to the Secretary of War; report of interdepartmental conference between representatives of the War Department, Navy Department, Treasury Department, and Department of Commerce and Labor convened at the request of the Secretary of the Navy, dated 11 Feb. 1911, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[47] Letter, dated 18 April 1911, the Secretary of the Navy to Commandant, Navy Yard, Mare Island, Calif., letter, dated 24 Aug. 1911, commanding officer, U.S.S. *Buffalo*, to the Secretary of the Navy, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[48] E. H. Dodd, "Alaskan Naval Radio Expedition, 1912," Journal of the American Society of Naval Engineers, vol. 25, 1913, p, 295.

of gale strength and torrential rains, this expedition, which was to be away from Mare Island Navy Yard for a period of 6 months and 3 days, erected and established stations at Unalga, St. George, Kodiak, and Cardova, · and refitted the stations at St. Paul and Dutch Harbor. All of these stations were equipped with the latest quenched-gap transmitters and could maintain communications with stations on the Pacific coast at night each utilizing frequencies between 165 and 300 kc.[49] It is of interest to note that these frequencies were considerably lower than those used by other Navy coastal and insular chains.

ENDEAVOR TO FORCE THE FLEET TO USE RADIO FOR TACTICAL PURPOSES

Todd was extremely cautious in his endeavor to develop the tactical use of radio within the fleet. His personal friend, Lt. Comdr. T. T. Craven, USN, had been assigned the fleet training desk in the Division of Operations, Bureau of Navigation. Craven, who like Todd, later became a Director of Naval Communications, shared his concern over the lack of radio organization, both ashore and affoat. In an attempt to point out the deficency, Craven decided to write into the "Target Practice Instructions, 1912,"[50] the requirement that all visual signals made during the practice would be paralleled by radio signals. To write up the necessary instructions, he procured the services of Lt. S. C. Hooper, USN, who at that time was an instructor in the Electrical Department, U.S. Naval Academy.[51] The final draft of the radio portion of these instructions required each ship to key its transmitter from the bridge and to install a receiver in that location, connected to a separate small antenna, in the manner described in the previous tests

[49] Letter, dated 4 Dec. 1912, Radio Officer in Command of Alaskan Radio Expedition to Commandant, Navy Yard, Mare Island, Calif., files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[50] These were for the fiscal year, beginning 1 July 1912.

[51] Hooper had become interested in radio as a result of the untilization of the U.S.S. *Chicago's* radio following the San Francisco earthquake. Shortly after that incident he was transferred to the U.S.S. *Yorktown* and, when in Mare Island, contacted Lt. E. H. Dodd USN, who was in charge of Pacific coast radio stations. Through him he obtained the necessary parts to construct both a transmitter and a receiver, and while on the *Yorktown* constructed the receiver. However, before he was able to assemble the transmitter he was transferred to the U.S.S. *Perry*. He took the receiver and the parts for the transmitter with him to the *Perry* where he found the commanding officer sufficiently interested in his project to offer such assistance as the destroyer could afford. The transmitter was soon assembled and was given some official tests with the flagship, but due to use of the electrolytic detector these were unsuccessful, because the vibration on the destroyer was sufficiently intense to break the contact between the wire and the fluid. Later on he related his experience to Dodd, who pointed out the error, but encouraged Hooper to continue and to endeavor to obtain a radio assignment or his approaching tour of shore duty. He applied to the Bureau of Navigation for a postgraduate course of instruction in radio, and in answer received this classic: "The Bureau appreciates your interest in improving yourself in applying for a postgraduate course but regrets to state that it is not the intention to order an officer to postgraduate course in radio, as this branch will not require the services of officers. Therefore it is suggested that you might desire to apply for a course in broader engineering." This did not appeal to him so he let the matter rest for a few months, after which he decided that since there were only two officers assigned to full-time radio duties, Todd at the Navy Department and Dodd on the Pacific coast, the only possibility of obtaining such a shore assignment would be to become an instructor in the Electrical Department at the Naval Academy. He was successful in obtaining this but on arrival was chagrined to find that he had been assigned as an instructor in the Seamanship Department. However, after a few months he was able to get assigned to the Electrical Department as the instructor in the small radio course which was given midshipmen. In endeavoring to qualify himself as an instructor he obtained Todd's permission to visit the U.S. Naval Radio Research Laboratory for talks with Dr. Austin. Todd became interested in Hooper and when Craven was looking for someone to draft the instructions for the target practices he recommended him. (Hooper, "Navy History —Radio, Radar, Sonar", transcript of recordings, Office of Naval History, Washington, D.C., p. 15).

conducted by the U.S.S. *Connecticut,* and the assignment of a separate frequency for each of the participating battleship divisions.[52]

THE FIRST U.S. NAVAL RADIO FREQUENCY PLAN

The requirement for the use of separate frequencies for each of the battleship divisions as contained in the "Target Practice Instructions, 1912" necessitated the formulation of a standard frequency plan. In midsummer 1911, the Bureau of Steam Engineering issued the first U.S. Navy radio frequency plan. As compared with later ones, this was extremely simple and only designated the use of specific frequencies for calling purposes, with the remaining ones to be assigned by the fleet commanders. In accordance with international usage, 500 kc. designated "F", was assigned as the frequency for calling ships and shore stations. Three hundred kc., designated "J" was provided shore stations as a calling frequency. Exceptions were made in the cases of the U.S.S. *Birmingham, Salem, Delaware, North Dakota, Michigan* and *South Carolina,* fitted with lower frequency transmitters, in that they also were permitted to use 300 kc. for calling distant ships or stations. The portion of the radio spectrum from 1,000 down to 37.5 kc. was divided into 26 frequencies designated "A" through "Z". Frequencies "A" through "E", separated by 50 meters,[53] were assigned ships fitted with "short-wave" apparatus and "G" through "I", separated by 100 meters, to ships fitted with "long-wave" apparatus. Frequencies "K" through "P", spaced 100 meters apart, "Q" through "V", spaced 400 meters apart, and "W" through "Z", beginning at 60 kc. and separated by 1,000 meters, were authorized for the use of both ships and stations in the transmission of messages. Frequencies midpoint between those already cited were designated by a combination of the enclosing designations, such as "AB", "BC", etc., and were authorized for the use of ships fitted with transmitters which could not be tuned sharply.[54]

Is is of interest to note that this plan called for the elimination of the transmission of secondary frequencies by proper adjustments and calibrations of transmitters to provide sharp tuning.[55]

The directive stated that, at such time as a sufficient number of ships had been fitted with quick frequency changing devices, instructions would be issued on the shifting of frequencies, but in the meantime calling frequencies "F" and "S" could be utilized for the transmission of messages. This weakened the directive but, without its inclusion, it is most probable that radio communications in and with the fleet would have become completely disorganized as there was insuffìcent qualified talent to insure its accomplishment. To assist the various ships in meeting the requirements, the Bureau sent Ens. Charles H. Maddox, USN, to aid in calibrating the transmitters.[56]

THE RADIO (ARLINGTON), VIRGINIA, STATION

Construction of the two buildings and one 600- and two 450-foot towers comprising the station then known as Radio, Virginia was begun in 1911. As designed, one building was for housing the transmitter and providing spaces for offiices for the Superintendent of the Naval Radio Service. The other building was for housing the receiving facilities and providing operating

[52] Infra, ch. XV.

[53] Under this plan, in consonance with the practice at the time, these frequencies and the spacing between them were specified in wavelengths. Translated into frequencies the spacing is not uniform.

[54] Letter, dated 25 July 1911, Bureau of Steam Engineering to All Ships and Stations, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[55] Ibid.

[56] Ibid.

spaces and quarters for the crew. The original design had called for three 600-foot towers, but lack of funds necessitated the limiting of the height of two. The contract for these stipulated a completion date of 30 March 1912, but a steel strike delayed their completion until 10 December of that year. The buildings, which were constructed under the supervision of the Bureau of Yards and Docks, were completed prior to that date. The main flattop antenna, triangular in shape, consisted of two sections 355 feet in length and one of 240 feet. The shorter section contained the "downlead" at its center. The natural period of this antenna system was about 137 kc.

The Fessenden 100-kw. synchronous rotary spark transmitter and a 35-kw. Federal arc transmitter were installed prior to the end of 1912. On 13 February 1913 this first Navy high-power station was placed in commission.[57]

FINAL ACCEPTANCE TESTS OF FESSENDEN TRANSMITTER AND COMPARATIVE TESTS OF FEDERAL ARC TRANSMITTER

The U.S.S. *Salem* sailed from the League Island Navy Yard, Philadelphia, Pa., on 15 February 1913, for Gibraltar with National Electric Signaling Co. and Navy experts embarked. This voyage was for the purpose of conducting the final acceptance tests of the Fessenden apparatus and for making comparative tests between that transmitter and the Federal arc. During the tests Arlington transmitted on prearranged schedules, alternately using the Fessenden and the Federal transmitters. The receivers installed in the *Salem* were Fessenden's new heterodyne, the Wireless Specialty Apparatus Co.'s IP76 with crystal detector, and the Federal Telegraph Co.'s "tikker." The latter consisted of a fine wire held against a segmented rotating metal wheel which "chopped up" the incoming continuous waves into a mushy, nonmusical sound which spoiled the effect of the arc's signal. The spark transmitter signal was received by the heterodyne with a "shushing" sound but even with the "shush" it provided far better detection than the crystal. The arc transmissions as received by the heterodyne produced a still more efficient and pleasing musical note which the operator could vary to suit his own ear.[58]

The Naval Radio Research Laboratory's digest of the measurements taken on the *Salem* indicated that the arc, which induced only half as much current into the antenna as the spark, gave signals of approximately the same intensity at 1,500 to 2,000 miles when received by the "tikker" and were even superior when received by the heterodyne. Messages were continuously received from both the arc and spark in the daytime up to 2,1000 miles, and on one occasion the arc was heard during daylight while at anchor off Gibraltar. Both were heard at night at all times during the voyage to Gibraltar and return.[59]

In connection with these tests, it is of interest to note the comments quoted below which were made to Hooper in later years by Hepburn:

> When the *Salem* sailed, George Clark was on board with his paraphernalia to begin the tests that were to determine the cost of the Fessenden set in Arlington. He had been out many days, carrying out both day and night tests and he had just about reached, as we thought, the limit of clear reception from the original Fessenden set when I received a rather cryptic message from him. I knew he was trying to tell us something but I couldn't determine what. A little

[57] D. W. Todd, Lt. Comdr. USN, "The Arlington Radio Station," Journal of the American Society of Naval Engineers, vol. XXV, no. 1, Feb. 1913, pp. 60–63, The disestablishment of Radio Arlington was ordered on 28 June 1956, effective 1 July 1956. Deactivation ceremonies took place on 14 July 1956 at the site of the station. During the latter part of the 43 years of its existence it had been retained in a reduced operating status. (News Release, 28 June 1956, Department of Defense, Office of Public Information, Washington, D.C.)

[58] Letter, dated 15 May 1913, Subinspector Naval Radio Stations to Chief of the Bureau of Steam Engineering, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[59] Ibid., p. 1.

bit later I mentioned it to Dr. Austin and he couldn't make anything of it either. I said, "We will soon know when he gets to Azores." When he got to the Azores we received the same cryptic message from him. It was in a language he thought I would understand. I studied it over and said to Dr. Austin, "You know, Doctor, I think he is trying to tell us that the arc set in connection with the heterodyne is the very thing we and everybody have been looking for. Don't you think it would be a good idea now if we get in touch with Elwell and ask him if he can make a 100 KW arc. If he says he can, feels confident, and is willing to guarantee us certain reasonable minimum performance, then put up this proposition to him. If he will agree to supply us such a set at practically cost price on open bid, then let us immediately get out an advertisement for bids for 100 KW or 150 KW sets specifying continuous wave operations, not of course mentioning an arc, but naturally it would be the only equipment that could meet the specifications." We, on the other hand, would probably get a set at such reasonable cost that if it worked, we could look forward to building and outfitting the rest of the six high-powered stations for which we had an appropriation of one million dollars.[60]

. . . No other high-powered overseas installation of that sort had cost less than two and a half millions. When I proposed this to Austin he threw up his hands and would have none of it. He said all he had was his reputation and he couldn't think of lending approval to a proposition of that sort on the basis of such information as he then had. Well, I said I had no reputation to lose and I thought I would put it up to the Chief of the Bureau, Admiral Cone, and see if he was willing to take a flier. When I explained it to Admiral Cone he laughed and said that it did look like a killing if it would work and he was willing to trust my judgment in the matter. I told him we would have the contract drawn in such form that we could walk out of it without much monetary loss if it didn't work. Insofar as the Bureau's reputation for good engineering practice was concerned he could blame that all on me. I also warned him that if we did ask for these bids within forty eight hours he would have every responsible manufacturer of spark sets in the country descending on him to learn what he was trying to celebrate. They would all say it was ridiculous and they would all think we had some trick up our sleeve. He said he could handle them, go ahead. I don't recall now why it was a matter of importance to get this advertisement out so quickly, but we did, and not only that, we advertised for the bids to be submitted within the least time the law allowed. As I had predicted to Admiral Cone, he did have an avalanche descend upon him to protest . . . . The long and short of it was that it went through and the arc did work . . . .[61]

[60] Hooper, op. cit., pp. 262, 324.

[61] Ibid., pp. 324–325.

Undamped waves, as emitted by the arc transmitter ("the Navy's darling"), were eventually to sound the "death knell" of the spark transmitter to the extent that, in time, it would be illegal to intentionally utilize such equipment. However, the arc alone did not bring this to pass, but it did pave the way. As previously forseen, the Fessenden apparatus failed in maintaining communications with ships up to 3,000 miles. Since it was not capable of meeting the contractural specifications, a compromise settlement was effected.

DEVELOPMENT OF TRANSMITTER FREQUENCY CHANGER

Other than testing the battle radio sets, the Navy had as yet made no attempt to utilize more than one transmitter at a station. The normal practice was to make contact with a station on a calling frequency and then to shift to another for the delivery of messages. Transmission and reception were never accomplished at the same time. The "Target Practice Instructions, 1912" were slightly in variance with the previously planned use of the battle sets in that the main transmitter was to be used, keyed remotely from the bridge. With but one transmitter, frequency shifting, a bothersome, time-consuming process, was required quite often. The antenna lead had to be plugged or clipped to the proper turn on the antenna coil for the desired frequency, the same thing had to be done with one lead from either the condenser or spark gap, and then the antenna coupling had to be varied until the proper amount was obtained as indicated by an ammeter in the antenna circuit. Often, when these positions had once been determined, various means were used to speed up the shifting process, but even these took time. This was bad enough under normal conditions but in wartime would have been absolutely impractical.

Clark began work on this problem in 1911 and designed a crude device to eliminate the cumbersome procedure. Essentially, he replaced the physical movement of the antenna coil by an equivalent electrical movement, in which both the antenna and ground contacts were moved up or down along a stationary coil until the proper coupling was obtained. Additionally a single dial controlled the movements of three insulated arms, which made the correct contacts on the primary coil and for the ground and antenna on the antenna coil in such a manner that by one simple movement the circuit was immediately tuned to a frequency as indicated on a calibrated dial. This idea was later improved by Mr. Guy Hill, Radio Aid at the New York Navy Yard. Navy Frequency Changers, Marks II and III, soon became standard on all Navy spark transmitters. These devices were later modified for use with the arcs.[62]

APPROVAL OF NAVY HIGH-POWERED RADIO SYSTEM

Although the early tests of the 100-kw. synchronous rotary spark transmitter indicated that it would fail to meet the manufacturer's contractural guarantees, they did prove that it could, for lack of one better, be used to provide the interlinkage between stations of the planned high-powered network.

In appearing before the House Naval Affairs Committee, in February 1912, in support of his requested budget for fiscal year 1912, the Chief of the Bureau of Steam Engineering asked for funds for these stations, stating:

> . . . I would like very much to have added to this appropriation an item of $1,000,000 for the construction of wireless telegraph stations . . . A part of the naval policy of the United States . . . is looking toward preparing to protect our interests in the Pacific. The distances are long, the communication is very uncertain, and cables are very expensive. I have had men working on this for a year and a half now, and they report to me that we can cover the Pacific with wireless, so as to have communication at any time day or night, and I can get guarantees from wireless-telegraph companies that they will install apparatus that will do this. The whole project will cost about $1,000,000. . . .[63]

As a result of this request, the Act of Congress of 22 August 1912, contained this provision:

> Toward the purchase and preparation of necessary sites, purchase and erection of towers and buildings, and the purchase and installation of machinery and apparatus of high-power radio stations (cost not to exceed one million dollars), to be located as follows: One in the Isthmian Canal Zone, one on the California coast, one in the Hawaiian Islands, one in American Samoa, one in the island of Guam, and one in the Philippine Islands, four hundred thousand dollars to be available until expended.[64]

In later legislation and prior to completion of all high-power stations listed, the authorization of one million dollars was increased to $1,500,000.[65]

APPROBATION

The work of the Bureau of Steam Engineering and its U.S. Naval Radio Laboratory created considerable interest and stimulus in radio as a means of reliable long-distance sea communications. The quantitative measurement methods devised by Dr. Austin were in use by radio engineers and were aiding in the construction of more satisfactory equipment by the firms interested in producing improved apparatus. No finer tribute can be paid than the state-

[62] "Radioana," op. cit., Clark, "Radio In War and Peace," pp. 112–113.

[63] "Estimates Submitted By The Secretary Of The Navy 1912", hearings before the Committee on Naval Affairs of the House of Representatives, appropriation bill subjects 1912, 62d Congress, 2d sess. 1912–13. (Washington Government Printing Office, 1912), p. 472.

[64] Compilation of Annual "Naval Appropriation Laws from 1883 to 1912", "Navy Yearbook 1912," Compiled by Woodbury Pulsifer (Washington Government Printing Office, 1912), p. 718.

[65] "Navy Yearbook 1916," Compiled by B. R. Tillman, Jr., (Washington Government Printing Office, 1916), pp. 394–395.

ments contained in the *Electrical World* early in 1913:

. . . With the establishing of reliable data relating to transmitter power delivery, signal intensity, distance and character of country separating the sender and the receiver, this branch has become a matter of engineering very nearly as exact as any other division of electrical science. The adoption of uniform operating methods of generation and more rugged receivers—which are of suprising sensitiveness—together with high-musical sparks for penetration of atmospheric disturbances, has made long-distance wireless telegraphy fit for management on business like principles . . . By the use of transmitters generating sustained streams of waves, working in connection with very delicate yet very stable receivers, and operating at the high speeds of automatic telegraphy, a new era of commercial radio communication seems likely to break upon us at any moment.

. . . Arlington's piercing high-pitched whistling spark has already been heard in Nova Scotia, in the Canal Zone and on the Northern Pacific coast . . . *Salem* is expected to receive from Arlington over more than 3000 miles, and upon its completion our Government will be in possession of the first link in the group of installations, which are expected to be models of efficiency and certainty in operations.[66]

The Navy's installation of quenched spark gaps and its endeavors to utilize various frequencies for correspondence and tactical purposes had accomplished much toward the reduction of interferences.

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[66] "Long-Distance Radio-Telegraphy", Electrical World, (McGraw-Hill Pub. Co., New York), vol. 57, no. 2, 11 Jan. 1913. At the time this article was written the Federal arc transmitter had not been comparatively tested by the Navy.

CHAPTER XIV

Early Navy Effort to Develop Aircraft Radio

EARLY NAVAL INTEREST IN AIRCRAFT

Lt. George C. Sweet, USN, who as an ensign had witnessed the failure of the Langley flight tests on the Potomac in 1903, is credited with being the first naval officer to fly in an aircraft and to evince interest in aviation as an adjunct to the Navy. His interest came close to being short lived. On 17 September 1908, a demonstration of aircraft was staged from the parade grounds at Fort Myer, Va. Sweet and Lt. Thomas E. Selfridge, USA, first aviator of that service, were scheduled to take flights. Selfridge, desiring to take an early afternoon train to New York, requested Sweet to trade flights, to which he acquiesced. The plane crashed, with Selfridge as a passenger, and he was killed. This disaster was sufficient to convince the Secretary of the Navy that the day of naval aviation was not yet at hand, but Sweet, with the backing of Rear Admiral Cowles, Chief of the Bureau of Equipment and brother-in-law of Theodore Roosevelt, recommended the Navy pursue the matter of planning for the utilization, buying, and testing of aircraft.[1]

Sweet envisioned an amphibious plane capable of carrying more than one person, and of such design that it could be carried on board ship and launched therefrom for scouting. A minimum speed of "at least 40 miles an hour appeared to be a requirement and it should be capable of hovering, if such could be accomplished. A radio installation was essential." He felt that in the then existing state of "aeroitation," as he termed it, these requirements were entirely practical, and he foresaw the great contribution radio-equipped aircraft could make to the scouting powers of a fleet and as a protection against enemy attack. Additionally, he stressed the point that since underwater minefields had been detected from the air, why could not approaching submarines be detected in the same manner? In a rather convincing letter he recommended that the Navy obtain planes meeting the above mentioned requirements, place them in the hands of its own personnel, and train them as rapidly as possible. In the last paragraph of his letter he noted:

> Attention is invited to the great encouragement being given to inventors of like apparatus abroad, particularly in Germany and France. It is believed that the Department should not be behind in this, as the most practicable flying-machine at present is the invention of a citizen of the United States, and it would seem advisable to lead other navies in this as in the past had been done in other features.[2]

Sweet's letter was referred to the General Board of the Navy, of which Dewey was the president. The latter's interest was aroused and he recommended that the Bureaus of Construction and Repair and Steam Engineering consider the problem of providing space for aircraft in the plans for a new scouting vessel. Although this recommendation was not approved, it did lead to the establishment of an elementary aeronautical organization in the Navy De-

[1] Archibald D. Turnbull and Clifford L. Lord, "History of United States Naval Aviation" (Yale University Press, New Haven, 1949), pp. 4–5.

[2] Ibid.

partment. Little encouragement was manifested in the idea of which one admiral remarked, "Why waste the time of the General Board on wildcat schemes?" [3] The failures of the Langley and Selfridge flights were not easily forgotten. However, the Wright Brothers had succeeded in meeting U.S. Army requirements and sold the War Department one plane in August 1909.[4]

In the spring of 1910, followed the occasion of his successful flight from Albany to New York, for which he was awarded the New York World's $10,000 prize, Mr. Glen Curtiss announced in a speech in New York City, "The battles of the future will be fought in the air." [5] During the last few days of June 1910, Curtiss gave an exhibition of "bombing" floating objects on Lake Kueka, near Hammondsport, N.Y. This had been arranged by the New York World.[6] Dropping short lengths of lead pipe from altitudes ranging from about 300 to 900 feet, he finally succeeded, on the second day of the tests, in scoring hits on a 90- by 500-foot target simulating a dreadnought. While these demonstrations served to emphasize the shortcomings of aircraft to many of the military observers, the World became critical of the Navy and in its editorials deplored its willingness "... to squander $18 million for one battleship when there is already in existence a $5,000 flying machine capable of carrying enough brains, brawn, grit and nitroglycerine to send it to the bottom in an instant." [7]

The remarks of the World's correspondent concerning the above demonstration are of special interest in demonstrating the opinions then held:

> To the official observers the test demonstrated two important points:
>
> First—That no aeroplane can be made into an efficient war machine unless it is fitted for carrying two persons—one to act as pilot and attend the motor, the other to act as gunner.
>
> Second—That the dropping of projectiles is a waste of ammunition and that a prime necessity is a gun that can be aimed from overhead and which can carry its missile straight at the target.[8]

Worldwide interest of both civilians and military personnel was aroused and greater support for aviation in the Navy was obtained, when on 14 November 1910 Eugene Ely, a member of the U.S. Naval Aeronautical Reserve and a former pilot of the Curtiss Co., successfully launched a landplane from an 83′ x 24′ temporary "flight deck," erected on the forecastle of the U.S.S. *Birmingham,* and landed on the broad sandy beach of Willoughby Spit, Va., after a flight of 2½ miles. This was the first flight launched from a ship.[9]

THE NAVY PROCURES ITS FIRST AIRCRAFT

Following numerous other successful tests, Capt. W. I. Chambers, USN, who had been assigned the duty of watching aviation developments, persuaded the Secretary of the Navy to request the House Committee on Naval Affairs to recommend an appropriation of $25,000 for the purchase of the Navy's first planes. The act of March 4, 1911 provided this sum, and the Navy purchased two land planes, a Curtiss and a Wright, and a Curtiss "Triad" amphibian.[10] Clauses in the contracts provided that the firms train a pilot and a mechanic for each plane. Lt. John Rodgers, USN, scion of one of the most famous lines of American seamen, was selected to report for training at the Wright plant in Dayton, Ohio. Lt. John H. Towers, USN, later to become Chief of the Bureau of Aeronautics during World War II, joined Lt. Theodore L. Ellyson, USN, at the Curtiss plant in Hammondsport.[11]

[3] Ibid., p. 16.

[4] S. C. Hooper, "Navy History—Radio, Radar Sonar," transcript of recordings, Office of Naval History, Washington, D.C., p. 194.

[5] Turnbull and Lord, op. cit., p. 6.

[6] New York World, 1 July 1910, p. 1.

[7] Harold Blains Miller, "Navy Wings," (Dodd, Mead & Co., New York, 1937), p. 35.

[8] New York World, 1 July 1910, p. 1.

[9] Turnbull and Lord, op. cit., p. 11.

[10] Ibid., p. 17.

[11] Miller, op. cit., p. 90.

The Navy's first aviator was Ellyson. In July 1911 he qualified as a licensed pilot under the rules of the Aero Club of America. Rodgers and Towers qualified in August and September respectively. The three planes were delivered in October.[12]

THE NAVY DEVELOPS THE FIRST AIRCRAFT RADIO

As envisioned by Sweet, the early naval uses of aircraft were for spotting the fall of shot and for increasing the scouting ranges of ships. Both of these actiivties required the use of radio for the attainment of maximum results. Consequently, with the delivery of the aircraft, work was immediately commenced to adapt radio equipment for fitting into them.

The equipment used in the earliest attempt consisted of the Wireless Specialty Apparatus Co.'s IP76 receiver and a transmitter which used a Ford spark coil, connected to a short trailing wire and to the fuselage and guy wires of the plane. The operator of this equipment was an electrician named Range. It was powered by a small storage battery to which Rodgers objected very strenuously because of its weight. This equipment did not prove successful.[13] Following this, the task was assigned to Ens. Charles H. Maddox,[14] USN. Although not an aviator, he was a radio enthusiast and was keenly interested in its application to aircraft. He not only designed, developed, and installed the apparatus, but also operated the first successful set in an airborne aircraft.[15]

For his radio experiment, Rodgers selected the Wright plane which was built of wood, fabric covered, with many wires and fittings holding it together, and fitted with pontoon floats. It was a pusher with a 32-horsepower engine and chain-driven counter-rotating wooden propellers, which Rodgers referred to as the "Flying Windmill."

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[12] Ibid., p. 97.

[13] A. Hoyt Taylor, "Radio Reminiscences: A Half Century," (Office of Naval Research, Washington, D. C.), pp. 110–111.

[14] Maddox was born in Canada and appointed a midshipman from Pennsylvania. He graduated from the Naval Academy in 1909. As a boy he had been much interested in electrical subjects, especially telegraphy and telephony, and like Hooper, had learned Morse telegraph code well enough to qualify as a "fairly proficient operator." His first connection with radio in the Navy came in summer of 1908, when as a midshipman on the old cruiser *Chicago,* he had been detailed to the ship's radio room. This experience gave him an opportunity to learn practical operation of a radio station, of which he wrote "I took full advantage, especially the opportunity of surreptitiously sending personal messages of greeting to other midshipmen throughout the fleet," and "In those early days wireless telegraphy was a deep mystery in the Navy to all but a very few." After graduation from the Naval Academy in 1909 he was ordered to the battleship *Ohio,* and about 6 months later to the newly finished battleship *Michigan.* Early in 1911 he was on torpedo boat *Bailey,* which, with torpedo boat *Stringham,* was detailed to special duty in connection with radio transmission tests. Experimental work undertaken by these two ships was directly under his supervision. Prior to this duty Maddox spent several weeks under instruction at the U.S. Naval Radio Laboratory in Washington. While still attached to the *Stringham* he was assigned additional duty with the U.S. Atlantic Fleet to assist in the calibration of ships' transmitters in order that they might carry out the Navy's initial radio frequency plan and to observe results of use of radio as prescribed by "Target Practice Instructions, 1912." In February 1912 he was sent by the Navy Department to the Graduate School of Applied Science at Harvard University, where a course in "wireless" was being offered. There he studied theory of radio under Prof. George W. Pierce. Maddox was the first U.S. naval officer to receive postgraduate training in this subject and acquired a high reputation in this field. During the summer vacation of 1912, between semesters, he was ordered to the U.S. Navy Experiment Station, Annapolis, Md., for the purpose of investigating practicability of applying radio to an airplane. The Navy's air arm then consisted of the three aircraft previously noted, which were housed in canvas tents on the shores of the Severn River across from the Naval Academy. It was while at the Experiment Station, that, in July, he developed the Navy's first successful aircraft radio set. Maddox retired as a captain on 1 June 1946. (Encl. to letter, dated 29 May 1939, C. H. Maddox to George H. Clark, Department of Information, Radio Corp. of America, New York, N.Y., entitled "Memorandum for Mr. G. H. Clark, RCA, New York.")

[15] Hooper, op. cit., p. 184.

The generator which provided the radio set with power was designed to be light and driven in such a manner that it would not interfere in any way with the safe and efficient working of the aircraft engine. It was mounted on the lower wing and driven from the flywheel of the four-cylinder airplane engine by a leather belt. The antenna system was designed to be capable of radiating freely, to avoid possibility of creating a short circuit, to be properly tuned while on the ground and not require further adjustment when airborne. The original idea was to use a fine trailing wire but Rodgers objected to its dangling. The system finally devised consisted of four flexible stranded copper wires spread under each of the wings and secured to bamboo spreaders 8 feet long, made of fishing poles bought at a fish market in Annapolis. Being limited to a total weight of 40 pounds for the radio apparatus, Maddox was presented with a difficult design problem. The set, which was a modification of Navy equipment, consisted of a 250-watt 500-cycle self-excited generator and transmitter with a quenched gap. It was contained in a small case and mounted just behind the copilot's seat, which was simply a board on the lower wing. Maddox stated that "one sat on the lower wing like riding on a duck's back." The receiver, which consisted of a crystal detector and magnetic amplifier, was contained in a small wooden case measuring about 3"x7"x9". This was an experimental design built by the Wireless Specialty Apparatus Co. It was suspended from a sling around the operator's neck. Ordinary headphones were used, over which Maddox wore a tight-fitting, soft leather helmet. A double-pole, double-throw, send-receive switch was attached to a strut within reach of the operator.[16]

During the tests Maddox sat beside Rodgers with the telegraph key and the hot-wire ammeter strapped to his right and left legs and a screwdriver and monkey wrench in his hands. The wrench could be laid down behind him on the wing because it was heavy enough not to blow off. These tools were kept handy to tighten up bolts, nuts and screws of the engine casing that frequently worked loose from vibration. He related that on one occasion while sending signals, he received a poke in the ribs from Rodgers who had just heard a ping, which meant that a nut had come off a bolt on the engine and nicked the propeller. So great was the vibration in the air that as a result of numerous overhauls and the resulting badly worn nuts, it was not unusual for one to come off.[17]

During the tests only very strong signals emitted by nearby stations could be heard above the engine and ignition noises and the vibration of the plane. On 26 July 1912, at an altitude of 300 feet, Maddox succeeded in transmitting, "We are off the water, going ahead full speed on a course for the Naval Academy," which was received by the U.S.S. *Stringham* over a distance of 3 nautical miles. Later in the tests the transmissions of the aircraft were received at distances up to 15 miles by both the torpedo boat and by the Naval Academy radio station.[18] Maddox wrote, "These were the first radio messages ever received from an airplane radio transmitting set in the United States and probably in the world. Elated, Chambers had visions of ranges of 50 miles and talked of "no more homing pigeons." [19]

Maddox's pioneer set, an ingenious and notable first step, was the beginning of future efforts to provide reliable and efficient aircraft radio communication. His work was but little appreciated at the time for it was not until 22 years later, as a result of action instigated by Hooper, that he received a letter of commendation from the Secretary of the Navy in recognition of his work.[20]

[16] Hooper, op. cit., pp. 187–189.

[17] Ibid., p. 189.

[18] A. Hoyt Taylor, op. cit., p. 110; Hooper, op. cit., p. 190; Maddox, op. cit., p. 6.

[19] Turnbull and Lord, op. cit., p. 25.

[20] Hooper, op. cit., p. 190.

Following this, however, little was accomplished in improving aircraft radio until 1915 and then only under the pressure of necessity. Radio was not then popular with aviators who generally considered the additional weight a handicap to safety and its utilization an undesirable personal burden.

CHAPTER XV

United States Naval Radio Prior to World War I

THE UNSATISFACTORY FLEET COMMUNICATION SITUATION

Intrafleet communications had reached a low ebb of satisfactoriness by 1911. The conditions are well described by a letter of Capt. W. F. Fullam, USN, commanding the U.S.S. *Mississippi*. In this he had observed:

It is my firm belief that simplicity and certainty have never been properly studied in connection with Tactics and Signals in our Navy, and in consequence it is my opinion, that since Admiral Walker's Squadron in 1887-1890, we have not improved one iota as regards Tactical Signal Book or the System of Tactical Signals needed either in time of peace or war. In some respects our system of flag signals is not as good as it was in 1889. Our slowness in these matters is to me incomprehensible and inexcusible. We talk a great deal, drill a great deal, work very zealously and accomplish little or nothing in the few vitally important points that would tell in time of war.

In the event of hostilities the useless complexity of our Tactical and Signal System could be clearly demonstrated. We have failed to develop or employ the wireless, as a means of signaling . . . The present systems, so far as they relate to battle or preparations for battle should be blown sky-high. It is no exaggeration to say that dynamite is needed for this purpose—now, not a month or a year hence, but now.

And right here let me say that the one great trouble—the secret of slowness in our Navy, is that officers either have no opinions, or if they have any they are not sufficiently encouraged to speak them out, or they are afraid to do so except in a namby-pamby way. It too often happens that an officer who really proposes to do something is stigmatized as a radical or extremist and his voice is drowned by the self-styled 'solid men' who are quite unmindful of the distinction between solidity and density.

By the way, what particular individual, bureau or institution in our Navy is supposed to consider and keep our Tactical and Signal System up to date? [1]

Concerning the conditions existing in radio communications Hooper, years later, commented:

As for radio discipline at that time—there was none whatsoever. The fact that an operator was able to send a radio message from one ship to another or to a shore station seemed so thrilling to his captain that each one thought his own operator was the "boy wonder" and gave him absolute authority to send whatever he pleased. If the flagship operator was unfriendly with the operator in another ship he would delay him until all the other operators had transmitted their messages. If a ship was fitted with a more powerful transmitter than others the operator would usually deliberately unsurp the air to the detriment of all others. There were more personal than official messages and more operator conversation than messages.[2]

FAILURE OF PRESCRIBED TACTICAL USE OF RADIO

When the time arrived for the autumn target practices in 1911, Craven, Hooper and Maddox were given additional duty orders to observe the practices and to make

[1] Letter, dated 2 Jan. 1911, W. F. Fullam to R. D. White, Flag Lieutenant, Atlantic Fleet. Naval War College, Archives, Newport, R.I. Fullam while Superintendent, U.S. Naval Academy, during 1914–15, with a broad perspective of the educational requirements and of training of naval officers, broadened the course of instruction of the Academy.

[2] S. C. Hooper, "Navy History—Radio, Radar, Sonar," transcript of recordings, Office of Naval History, Washington, D.C., pp. 37–38.

reports and recommendations to the Navy Department.[3]

One objective of the practice was to ascertain to what extent the firing ships could receive tactical and general signals under battle conditions.[4] The plan involved the transmission of tactical signals by radio for receipt by the firing ships during the time their main batteries were in action while the ship towing the target attempted to create interference. As a safety precaution the signals were paralleled by flag hoists.

When the practices commenced, Hooper took station in the flagship radio room to monitor and note discrepancies. To his amazement not a single ship carried out the instructions. Following the firings he went up to the bridge and found that the receiver required there was not installed. Further investigation indicated that none of the ships had made the required installations. The fact was that the instructions on this subject had been passed to the operators. These men did not have the authority or knowledge to handle the situation beyond the actual transmitting and receiving and had not carried out the directive. Sadly, he reported the situation to Craven who invited the admiral's attention to the apparent oversight. The ships were instructed that, on the next day, they would fully comply with all the "Target Practice Instructions," including the chapter pertaining to the use of radio.

The next morning Hooper, at his monitoring post, found a few ships attempting to carry out the instructions but with little success. In a later investigation it was disclosed that only one division had exercised in this manner prior to the practices.[5]

[3] Enclosure to letter, dated 29 May 1939, C. H. Maddox to George H. Clark, entitled "Memorandum for Mr. G. H. Clark, RCA, New York", pp. 2–3.

[4] Enclosure to letter dated 7 Oct. 1911, Secretary of the Navy (Division of Operations) to Bureau of Steam Engineering, "being a report of wireless tests held in the Fleet in accordance with the instructions contained in the 'Rules for Autumn Practice 1911'."

[5] Hooper, op. cit., p. 35.

ASSIGNMENT OF ATLANTIC FLEET RADIO OFFICER

In submitting their report to Craven, both Hooper and Maddox, independently, pointed out the obvious lack of supervision of radio afloat and recommended the assignment of a qualified officer to the staff of the fleet commander. Craven concurred in the recommendation and was successful in convincing the Chief of the Bureau of Navigation that something must be done to improve intrafleet radio communications. The billet was established on the staff of the Commander in Chief, U.S. Atlantic Fleet, and Hooper was assigned this duty.[6]

Concerning Hooper's assignment Maddox wrote:

> At the Navy Department I was asked if I knew of an officer of the rank of Lieutenant who possessed the specified qualifications (being reminded that my own rank of Ensign barred my serving on an Admiral's staff). I had recently become acquainted with Lieutenant Hooper . . . I had learned he was interested in radio . . . I suggested that he would be an admirable choice. When I returned to Annapolis from Washington I informed him that his name was under consideration for appointment as Fleet Radio Officer of the Atlantic Fleet, and recall his expressed indignation at the threatened abrupt termination of his first tour of shore duty. However, after being summoned to the Navy Department he apparently was persuaded that this was a golden opportunity, and his appointment immediately followed . . . Due to his genius and continuous association with naval radio since that time, the United States Navy has the most extensive and efficient radio system of any navy in the world today.[7]

On his 27th birthday, 16 August 1912, Hooper reported to Rear Adm. Hugo Osterhaus, USN, Commander in Chief of the Atlantic Fleet, for duty on his staff as Fleet Radio Officer. He quickly discovered that the establishment of the billet did not automatically establish his position. Osterhaus, not wishing to increase the number of officers on his staff, had objected strenuously to the creation of the new billet. To overcome his objections the Bureau of Naviga-

[6] Ibid., p. 36.

[7] Maddox, op. cit., "Memorandum for G. H. Clark, RCA, New York," pp. 3–4.

tion concurred in his suggestion that the billet should be combined with the existing one of fleet tactical and athletic officer. All these functions were assigned Hooper. He was far from qualified as an athletic officer, and he found that duty time-consuming and so demanding that he could only perform his radio duties by working long hours each day.[8]

ESTABLISHMENT OF RADIO CIRCUIT DISCIPLINE

Hooper quickly became aware of the lack of supervision and discipline by personally observing the situation during many hours of monitoring the fleet circuit. The operators in the other ships, feeling secure from identification and being opposed to any officer supervision over a field which they had become accustomed to consider their very own, did everything possible in their endeavors to defeat him in his attempts to exercise supervision. After long hours of monitoring he could reasonably identify the various transmitters by their tones. He then explained the unsatisfactory situation to the Commander in Chief who authorized him to release a form message under his name to be addressed to the commanding officers of offending ships.[9] When this message was received by an offending operator he was placed into a difficult position. Not only did he have to receive the message, but he also had time to think about his misdoings for some minutes before his commanding officer took summary action. The first operator who refused to acknowledge receipt of such a message was tried and convicted by court-martial. Information of this quickly reached the other operators, who took due notice. Slowly, but steadily, discipline was established and although there remained a few who would not accept the new order of things, most of the operators soon came to the realization that fleet communications were rapidly becoming more efficient.[10]

DEVELOPMENT OF THE FLEET RADIO ORGANIZATION

While all this was taking place, officers were being trained in operating and in procedures, for Hooper was well aware that no single individual could maintain discipline of the air. In spite of his objections to establishing the billet of fleet radio officer, within a few weeks of Hooper's reporting for duty and upon his recommendation, Osterhaus did order the commanding officers of all battleships, flagships of cruiser and gunboat divisions, and flotilla flagships of destroyers to designate an ensign as radio officer and to require him to become proficient in operating and in procedure and after a specified date to take the afternoon radio watch. Other ships were directed to assign radio duties to an officer as additional duty but they were not required to become operators. Many of these young officers became quite proficient and interested and became the nucleus of a group which would later do much to improve naval communications.[11]

IMPROVEMENT OF OPERATORS' CAPABILITIES

Static was blamed for many things, it being a fine excuse for a lazy or incapable operator and, up until the time when sufficient officer supervision became available, there was little that could be done because the commanding officers could not determine whether or not static had actually interfered. There appeared only one solution to this problem—the elimination of static as an excuse for nonreception of messages—

[8] Hooper, op. cit., p. 47.
[9] Ibid., pp. 39–40.
[10] Ibid., p. 40.
[11] Ibid., pp. 40–41.

so an official order was issued and posted in all radio rooms, "Henceforth static disturbance will not be considered as an excuse for nonreception of a message." As would be expected, this became shorted to, "Henceforth there shall be no static," and Hooper found himself on the receiving end of considerable joshing. This order achieved the desired result, for the operators did become proficient in differentiating signal from static, even when the latter was almost enough to completely drown out the former.[12]

Another effort more calculated to improve operators' capabilities was the institution, in 1912, of competition between them with promotions as prizes. This proved so valuable that an expanded version was later made a specific part in determining a ship's battle efficiency.[13]

Additional stress was laid upon paralleling visual signals by radio, and some progress was made in the simultaneous use of several frequencies for tactical purposes. In a directive of the Bureau of Steam Engineering, the Commander in Chief was encouraged to use any of the standard frequencies "A" through "Z" for tactical purposes with the exception of "F", "G", "H" and "J." [14] However, Osterhaus would not permit his ships to be maneuvered by radio and would only execute his signals by flaghoist.[15]

RADIO ACCEPTED AS A METHOD OF TACTICAL SIGNALING

In 1913 Rear Adm. Charles J. Badger, USN, became Commander in Chief of the Atlantic Fleet. The new Chief of Staff was Comdr. Charles F. Hughes, USN. Hughes had been thoroughly briefed at the Navy Department concerning the unsatisfactory radio situation which existed within the fleet and of the necessity for improvement. At his suggestion Badger relieved Hooper of his additional duties as fleet tactical and athletic officer and gave full support of his plans.[16]

Discipline improved rapidly and a rivalry began between the signalmen and the radiomen with each group determined to obtain the acknowledgements of signals first. This materially improved the efficiency of both methods of signaling and created a healthy communications attitude.[17]

After observing conditions for a period, Admiral Badger decided that he would exercise the battleship divisions for an entire day by radio signals alone, except that visual signals could be used in an emergency. This was conducted successfully without a single mishap or failure in communications.[18]

It was fortunate that this exercise was held, for within the week a situation developed which necessitated maneuvering solely by radio signals. Sixteen battleships were about to proceed from Hampton Roads to Annapolis Roads. Just after the signal to get underway had been executed a terrific Chesapeake Bay squall descended accompanied by a howling wind. The visibility was reduced to zero and the situation became critical. Admiral Badger dared not let them anchor again as the current could have swept them into each other. Hesitating only for seconds to ascertain if all ships had their radio manned, he directed his signal transmitted by radio. It was quickly acknowledged by all but the U.S.S. *New Jersey*. Hooper, quite sure that the *New Jersey* had suffered a remote transmitter keying line casualty, advised the admiral that he believed she had received the signal, whereupon the latter ordered it

[12] "Radioana," G. H. Clark, "Radio in War and Peace", Massachusetts Institute of Technology, Cambridge, Mass., p. 134.

[13] Ibid., p. 135.

[14] Letter, dated 21 Oct. 1912, Chief of the Bureau of Steam Engineering to Commander in Chief, Atlantic Fleet, files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[15] Hooper, op. cit., p. 50.

[16] Ibid., p. 51.

[17] Ibid., p. 52.

[18] Ibid., p. 54.

executed. The storm continued for half an hour during which time all course and speeds changes necessary to lead the fleet through the narrow dredged channel were given and executed by radio with only the *New Jersey* unable to acknowledge. When the storm passed all the ships were in position astern of the flagship. Badger, relieved of his anxiety, directed that thereafter both radio and visual methods would be used for tactical signaling, and that they would be executed by whichever method was the faster.[19]

ESTABLISHMENT OF OFFICE OF SUPERINTENDENT, NAVAL RADIO SERVICE

As has been previously stated, the Bureau of Navigation did not consider it necessary to establish a new division when it became responsible for the operatons and administration of the Naval Radio Service following the reorganization of the Navy Department effective 1 July 1910. This opinion was quickly changed following the enactment of legislation regulating radio communications, effective 13 December 1912. This law required that certain naval shore radio stations be opened to commercial business on that date, and that charges be made for handling this traffic with the monies derived therefrom to be turned into the U.S. Treasury as miscellaneous receipts. In view of the increased workload and responsibilities resulting from the legislation and the growing importance of intrafleet and ship-shore communications, the Secretary of the Navy directed the establishment of the Office of Superintendent of the Naval Radio Service under the Bureau of Navigation, with headquarters at Radio (Arlington), Virginia, by General Order 240, dated 9 November 1912.[20]

[19] Ibid., p. 57.

[20] Annual Report of the Secretary of the Navy, 1913, (Washington Government Printing Office, 1913.), p. 124.

Among other things, the Superintendent was charged with:

> The preparation of regulations and issue of detailed instructions for the operation of stations in accordance with military efficiency, international agreements in force, and the laws effecting the operation of naval radio stations.
>
> Control of the commercial work handled by naval radio stations, including issue of accounting and operating forms, auditing commercial accounts, traffic agreements, and accounting with commercial and other government managements involved.

He was also charged with all matters pertaining to the operation of radio afloat and ashore, excepting technical control which remained with the Bureau of Steam Engineering, and was authorized to correspond directly within the naval service in regard to all matters on which he was authorized to take action in accordance with the procedure established for bureau and other offices of the Navy Department. He was also empowered to deal directly with private and commercial interests upon matters of reciprocal concern in the operation of naval radio stations, including questions of interference, and details of traffic agreements, rates, and accounting.[21] Unfortunately, he was not made responsible for devising and issuing codes and ciphers at this time.

The military control, inspection, and maintenance was vested in the commandants of the several naval stations, subject to Navy regulations, general orders, and instructions issued by the Superintendent, Naval Radio Service.

ORGANIZATION OF OFFICE OF SUPERINTENDENT, NAVAL RADIO SERVICE

Captain W. H. G. Bullard,[22] USN, was ap-

[21] W. H. G. Bullard, U. S. Naval Institute Preceedings, April 1912, "United States Naval Radio Service", p. 450.

[22] Bullard was born in Media, Pa., on 6 December 1866. He was appointed a naval cadet from that State in 1882 and graduated from the Naval Academy in 1886. In 1907 he was ordered to the Naval Academy to organize, and become the Head

pointed Superintendent of the Naval Radio Service on 13 December 1912.

In organizing his office, Bullard separated the Government and the commercial work, delegating the responsibility of the first to the Assistant Superintendent, Naval Radio Service, and the latter to the Head of the Commercial Department. The shore stations were divided by geographical considerations into three areas, Atlantic, Pacific, and Philippines. Each of the shore stations was placed under an area superintendent who reported directly to the Assistant Superintendent, Naval Radio Service, who was, additionally, the Atlantic Superintendent of Radio.

RADIO ORGANIZATION IN THE NAVY

Thus, the end of 1912 found naval radio communications well and completely organized for the first time. Management and operational control was vested in the Com-Navigation and delegated to the Superintendent of the Naval Radio Service; fleet operational control was vested in the Commander in Chief, subject to the direction of the Chief of the Bureau of Navigation and represented in the person of the Fleet Radio Officer; military command of the shore stations was under the commandants of the several naval stations, and in the fleet under the chain of command; technical control of all radio equipment, including research, improvement, design, and construction, remained under the Chief of the Bureau of Steam Engineering who delegated his responsibility to the Head of the Radio Division.

This organization was definitely different in comparison with that in the Army where total responsibility was vested in a Chief Signal Officer responsible only to the Chief of Staff of the U.S. Army. In the Navy it was a team under the guidance of the Superintendent of the Naval Radio Service with all members having definite responsibilities and authorities in the fields of endeavor in which best qualified. It was an organization constituted to cope with the stupendous task which confronted it and, although there would be many differences concerning the various solutions of the problems, no single individual could dictate since the organization provided a system of balances similar to that which has always existed in our Federal Government.

VERACRUZ—PROVING GROUND OF NAVAL COMMUNICATIONS

On April 21, 1914, after a year of strained relations with the revolutionary government of Mexico, President Wilson ordered the Navy to land troops, seize, and occupy the city of Veracruz. This occupation, which continued until November of the same year, was the proving ground of naval communications and pinpointed the deficiencies in our system.

The Commander in Chief, Atlantic Fleet, aided by Hooper, had instituted many reforms within the fleet which tended to enhance the tactical and strategic value of radio. Despite these improvements, the system was far from capable of providing the communication services required by a major war.

Radio, Virginia, had been established and equipped with the 100-kw. rotary spark gap and the 35-kw. arc transmitters in the endeavor to provide communication from

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of the Naval Academy's Department of Electrical Engineering. He served in this capacity for over 4 years and prepared the textbooks on this subject which were used by midshipmen for many years. When the Naval Radio Service was reorganized into the Naval Communications Service in 1915 he became its first Director. Upon completing this tour of duty he served at sea until early in 1919 when he again became Director, Naval Communications in which post, he served until he retired on 30 September 1922. During this period he was instrumental in encouraging the General Electric Co. to form the Radio Corp. of America. He was appointed chairman of the Federal Radio Commission in 1926, and while serving in this capacity he died on 24 November 1927.

the seat of government to fleet commanders distant from the U.S. mainland. These both failed to provide continuous direct radio communication between Washington and the ships at Veracruz, nor was such communication possible via Key West, Fla., the closest of the shore stations. Even had this station been successful, shipboard transmitters were of insufficient power to provide two-way communications. This necessitated stationing the U.S.S. *Birmingham* off Tampico, Mexico, to serve as a relay station between Key West and the U.S.S. *Wyoming*.[23]

With the *Birmingham* at Tampico, satisfactory day and night communications could be maintained provided the men-of-war of other nations, stationed off Veracruz and Tampico for the protection of their nationals, abstained from transmitting when either Key West or the *Birmingham* was sending. The spark transmitters fitted on the foreign men-of-war created totally disruptive local interferences.[24]

This situation necessitated the development of a time-sharing plan which was readily approved and adopted by the naval commanders of other nations present. Normally ships of three or four other nations were present and, under this plan, the United States was allotted a 2-hour period and the four other powers present 1 hour each. This resulted in there being periods of 4 or more hours when it was impossible to communicate between the Navy Department and its commander in the field. Although this condition could not be accepted during a major conflict, under the existing conditions a more satisfactory method could not have been devised.[25]

Mr. Arthur O'Brien, at that time a radioman in the *Birmingham*, years later related an incident which indicated the excellent state of training and capabilities of the operators on the *Wyoming* and *Birmingham*. This proficiency was the result of Hooper's personal supervision and was not generally the condition existing throughout the service. He stated that in one 2-hour schedule, plus an additional minute of encroachment on another country's time, he transmitted 9 messages totalling 3,800 code groups, at a speed better than 31 groups per minute, all of which were correctly received by the operator in the *Wyoming* without request for repetition. In contrast with this, the English, French, and German operators, transmitted at the rate of 12 code groups per minute, and repeated each group regardless of existing conditions, thus reducing their traffic handling capability to 6 groups per minute. Under the prevailing division of time it would have required 4 days for them to have handled 3,800 code groups.[26] This was just 2 months prior to the outbreak of World War I.

The Veracruz occupation was not without its humorous events, one of which occurred on the day the city was occupied. A Mexican gunboat, totally unaware of events, was steaming up the coast with several hundred reinforcements for the garrison at Veracruz. Long before it hove into sight it commenced to call the commercial shore radio station at that port. Because of the interference from the ships in the harbor the shore station was unable to hear the call and at the same time the continuous effort was interfering with the reception of messages by the ships. Finally, the fleet radio officer contacted the vessel and offered to relay the message. This offer was gratefully and courteously accepted. Hooper, on receiving it for relay, expecting it would be military in character, found it to be a message from the captain of the gunboat to his wife stating that he would be home for dinner. One can further imagine his chagrin when, on arriving at Veracruz, his ship was immediately taken into custody.[27]

Another humorous incident which occurred at the time was occasioned by the

[23] "Radioana," op. cit., Clark, "Radio in War and Peace."

[24] Ibid.

[25] Ibid.

[26] Hooper, op. cit., 11R.

[27] Ibid., 39R95.

press representatives whose only means of forwarding items to their papers was by naval radio. Under the existing condition of time-sharing it was necessary to limit the number of words these representatives could file with the flagship. Additionally, these press items were subjected to delays since they could not take precedence over official messages and at times were several days in reaching their papers. Consequently, a delegation of newsmen prevailed upon the Secretary of the Navy to direct Badger to have the press items transmitted direct to New York without relay. Compliance with this directive was simple enough but it produced no faster press since the radio station at New York was unable to receive the flagship's transmissions. The relay stations, although the press messages were addressed to New York without relay instructions, simply copied the messages and forwarded them on to their destination.[28]

COMMUNICATIONS SECURITY DURING THE MEXICAN INCIDENT

In addition to the failure to establish direct communications between Washington and the Atlantic Fleet flagship at Veracruz, the lack of secure means of communication quickly became apparent. Our Navy was slow in recognizing the requirements for a system to securely transmit orders and information by radio. This may have been the result of the early disregard and disinterest of many of its officers in this mode of communication. The "General Signal Book" of the United States Navy, 1908, was a revision of a publication of the same title which had previously been revised in 1898. It consisted of three books; the "General Signal Book," the "Tactical Signal Book," and the "Pocket Manual of Boat Signals." The "General Signal Book" included a telegraphic dictionary containing a syllabary of letters and syllables and a list of words and phrases numbered in a separate series, e.g.,

8856 ... Smuggle, ed, ing, s
344 ... Hydro

It further provided ". . . in connection with the Signal Code a Navy list of officers will be used, consisting of the names in the Annual Navy Register of the latest issue, each one of which bears a number for this purpose." Some security was provided by restricting the use of the telegraphic dictionary section to commissioned officers.[29]

In August 1912, the Commander in Chief, Atlantic Fleet, issued an unclassified, non-registered Radio Cipher "C", Atlantic Fleet. The letter of promulgation stated " . . . The code is divided into the following groups of signals to facilitate encoding and decoding.

First	Scouting Signals . . . Represented by 5-letter words.
Second	Letters, numerals and date signals . . . Represented by 3 and 4-letter words.
Third	Course and bearing signals . . . Represented by 4-letter words.
Fourth	A method of reporting latitude and longitude.
Fifth	A method of transposition of letters for sending messages not contained in the code.
Sixth	Call letters and code words for each portion of the force."

The code was considered versatile and provided for encodement either by numeral or letter groups or by the sequential number of the signal in its particular section. The cipher was of the transposition type, varied by the use of key words.[30]

On 12 May 1913, the Navy Department issued the "Battle Signal Book of the United States Navy, 1913." This was published as a "strictly confidential" registered publication. The letter of promulgation, signed by Josephus Daniels, Secretary of the Navy, stated, "The most important function of this code is that of a secret radio

[28] Ibid.

[29] Information from the Archives of the Registered Publication Section, Office of the Director, Naval Communications. Letter, dated 29 Dec. 1957, from Director, Naval Communications.

[30] Ibid.

code for tactical and battle orders." It followed the same format as the "General Signal Book" and was in three parts, "General Signal Book"; "Battle Signal Book," and "Deck and Boat Book." The "General Signal Book" included a section of vocabulary signals, " . . . a syllabary of letters, syllables, and words which may be used to form sentences which are not found among the general signals. It forms a good secret radio code for messages other than tactical orders requiring instant simultaneous execution, and will be of use as such and for telegraphic and cable messages much more often than for transmission by hoists of flags. The signals include geographical names and the names of all ships in the Navy." [31]

The "General Signal Book" was again revised and reissued on 22 October 1913. This issue followed the same format as that of 1908. Physical security and accountability were provided by limiting issue to officers only. For the first time this publication provided for encipherment of the code.[32]

In order to provide a code for training and privacy purposes, "The Service Radio Code of the United States Navy, 1914" was issued 10 February 1914. The letter of promulgation stated that it was " . . . issued for the purpose of furnishing a code, which being accessible to radio operators will be in frequent use, thus supplying desirable practice in the handling of code messages." This code was composed of four letter words each having a numerical equivalent, e.g.,

1658	CWYE	Barricade, ing, s.
11512	TZPJ	USS REHOBETH

Messages encoded in this system were prefixed by the word "radiocode." [33]

Despite these efforts, the Mexican incident caught the Navy Department totally unprepared to send secure communications. Messages, of which a more capable foe would have taken instant advantage, began to fill the air. Badger requested the Department to at least encode the vital and revealing portions of these and directed fleet units to encode all traffic. The request to the Department resulted in some slight improvement but not enough to deny information even to the most naive. The fleet auxiliary units were manned by merchant marine masters and crews who had had no training in communication security. In one instance one of our auxiliaries was anchored off Port Mexico at a time when the British Consul at the port desired to impart some information to the senior British naval officer at Veracruz. He requested the master of the auxiliary to transmit the message of about 200 words to the *Wyoming* for further delivery. The latter agreed to do so, but prior to the transmission he had it encoded verbatim, thereby presenting the British with about 200 groups of our relatively concise code.[34]

WORLD WAR I PRECIPITATES THE END OF AN ERA

Following the short-lived activity, fleet units remained in Veracruz to support the occupation. This period was used in improving our communication security and in drilling in the use of additional frequencies.[35] In August the Carranza forces entered Mexico City and virtually ended the Mexican incident.

At this time events in Europe had become critical. On 28 July, Austria precipitated World War I by declaring war on Serbia. Within a week the Triple Entente was at war with the Triple Alliance. Early in the morning of 4 August the German men-of-war in Mexican waters, notified of Great Britain's entrance into the conflict by a prearranged and apparently innocuous commercial message, weighed anchor and proceeded to sea. The British and French

[31] Ibid.
[32] Ibid.
[33] Ibid.

[34] Hooper, op. cit.
[35] Ibid., 11R.

commanders did not receive notification until late afternoon of the same day. They sailed that evening in pursuit of the German squadron.[36] By the time they were overtaken they had rounded Cape Horn and joined up with the German Pacific squadron. This augmented squadron defeated the Allies at the Battle of Coronel.

Shortly after this, Hooper was ordered to Europe as an observer of radio and communication in the European war zone. He was relieved by Lt. W. R. Furlong, USN, who had recently completed a postgraduate course in radio at Harvard University.[37]

FUTURE REQUIREMENTS OF NAVAL RADIO

The Radio Division of the Bureau of Steam Engineering, under the capable leadership of Hepburn, had made considerable improvement of equipment. The transmitters at all our shore stations and on the more important men-of-war had been equipped with either Telefunken, Chaffee, or Lowenstein quenched-spark or Fessenden rotary-spark gaps, all of which improved tonal quality and created less intereference. These improvements made it possible to transmit simultaneously on several frequencies in the same area provided transmitter power was kept sufficiently low. Many of the transmitters had "jury-rig" quick frequency changers, but these were of little value when operating in areas where the men-of-war of other nationals were equipped with open-spark gaps and were using full power. A decision had been reached to change to the continuous wave method of transmission, employing the Poulsen arc transmitter, and 10 30-kw. sets were under contract for fitting into the newer battleships. The ships which were to receive such transmissions required fitting with either heterodyne or a "tikker" receivers. This was, of necessity and economy, a long-range plan. Fortunately, by 1912 the oscillating properties of the three-element vacuum tube had been realized, and it could be used to generate the local oscillations required by the heterodyne method.[38]

Radio had "become of age" in the Navy but, as proved at Veracruz, it was far from maturity. Fortunately, the personnel involved were completely aware of this. There were many serious and pressing problems which required resolution among which were: increasing our ability to communicate by radio across the continent, with all our insular possessions, and with the fleet regardless of its area of operations; coping with interference; preventing an enemy from intercepting our signals or messages and turning this information to his advantage; increasing our own ability to interfere with or intercept the enemy's transmissions; devising a scheme of changing tactical calls when a ship shifted from one tactical position to another; increasing the ability to use several frequencies in the same area simultaneously; devising a means of shifting transmitter frequency quickly; reducing the vulnerability of radio equipment by installation below deck and behind armor; adopting a single telegraphic code for naval usage; developing secure code and cipher systems; developing direction-finding equipment in order to increase safety of navigation and for locating the sources of enemy transmissions; developing standard proceures for all types of signals and messages; pushing the development of aircraft radio; and, last but most important, to overcome the antagonism to radio which remained with many officers by forcing an appreciation by successful application, yet at the same time keeping the necessary balance between it and other types of communication. The solutions of these problems was necessary before the Navy could be provided with the communication system it would require in war.

[36] Ibid., 43R102–103.

[37] Ibid., 43R104.

[38] Ibid., 44R105.

Figure 15-1. Typical receiving room installation, 1914—equipment consisting of Type A (Cohen) receiver, Wireless Specialty Co. (1P76) receiver, crystal detector, ultraudion detector.

PART II

The Golden Age

CHAPTER XVI

United States Navy's Contributions to Radio and Communications Industries

PROLOG

This part of the history begins with the outbreak of World War I and relates the Navy's dominant position in the development and improvement of radio communications and equipment during our neutrality and preparedness period, and the months of our participation in the war and during the period of return to normalcy. It also relates the development of commercial broadcasting and the effect of this upon Government radio communications.

RADIO SITUATION AT BEGINNING OF WORLD WAR I

As we enter this period, sometimes known as the "Military Era of Radio," many innovations in radio equipment and operating techniques had become available, but they were not yet in general use. A few hundred miles was the maximum range of all but a few stations, although there were many claims to the contrary. Fleet operations at Veracruz had pinpointed our deficiencies and had indicated that reliable long-distance radio communications was still in the future. This necessitated continuing the maintenance of naval radio stations a few hundred miles apart along our coasts to relay messages to their final destinations. The radio stations at Arlington and Mare Island were interconnected by landline telegraph. The only naval radio station capable of transmitting distances of approximately 1,000 miles, was the one recently constructed at Arlington, Va. Congress had authorized and appropriated funds for six additional high-powered stations, but several years would elapse before they would be available.

Commercial radio communications, primarily ship-shore, were dominated by the Marconi Wireless Telegraph Co. of America. This company had succeeded in purchasing the assets of most of its competitors and practically possessed a monopoly. Although it had not succeeded in providing reliable commercial radio communications between the United States and Europe, it was endeavoring to develop or purchase equipment to meet this need. The Atlantic Communication Co., a Telefunken subsidiary,[1] was constructing a station at Sayville, Long Island. Another station was being built by Homag, a German concern, for a French communications firm.[2] Both of these stations were intended to provide trans-Atlantic communications. The Federal Telegraph Co. had established a fairly reliable night service between San Francisco and Hawaii. The Tropical Radio Co., a subsidiary of the United Fruit Co., had erected stations in Boston, New Orleans,

[1] Although the Atlantic Communication Co. had an American board of directors its actions were completley dominated by the Gesellechaft Fuer Drahtlose Telegraphie m.b.h. (Telefunken).

[2] This station was being constructed for the Compagnie Generale de Telegraphie sans Fil but the German Homag firm delayed turning it over after World War I commenced.

and at a few locations in Central America, and was maintaining company and limited commercial service between those points.

The use of the three-element tube as a detector and amplifier had brought about improvements in reception, but this device required further development and refinement to make it satisfactory and reliable. The discovery of its oscillating properties made the use of heterodyne reception feasible and, for the first time, a satisfactory means for the reception of continuous waves became available.

The improvements which had been made in the United States to the Poulsen arc transmitter made available a fairly satisfactory continuous wave transmitter. Although at the beginning of this period it was of relatively low power it was capable, with heterodyne reception, of reliably covering far longer distances than could be accomplished by the old spark transmitter despite all the efforts to improve its capabilities.

The General Electric Co. had succeeded after years of effort in developing the Alexanderson alternator for the transmission of low-frequency continuous waves. This was not yet in operation, and its cost and size would limit its use to long-distance transmissions.

Research and development of a low-powered tube transmitter for voice transmissions were being conducted, but for many years such transmitters would be restricted to short-distance transmissions except for experimental purposes.

THE U. S. NAVY'S ROLE DURING WORLD WAR I

During most of this decade improvement in radio communications fell upon the Navy. At the beginning of the period research and development of radio equipment had almost ceased in this country. The American Marconi Co. was depending almost entirely upon its British parent. The National Electric Signaling Co. was in poor financial straits, had terminated the services of Fessenden, and had almost ceased research and development operations. None of the manufacturers held sufficient patents to meet Navy specifications and moreover, were unwilling to provide equipment with the required ruggedness. This forced the Navy into design and manufacture.

At the beginning of World War I the preparedness program of this country required equipment in quantities large enough to create interest of commercial manufacturers who, feeling secure against patent infringement suits for equipment delivered the Government, were willing to meet Navy specifications. New manufacturers entered the field and sources became available which permitted the Navy facilities to be used primarily for research and design. Later, when court decisions indicated their liability for infringements of patents of equipments delivered to the Government, they were unwilling to continue unless the Government would assume the liability. This was done, and after the war the Government reviewed these infringements and recommended Congress appropriate funds for the payment of damages. Congress was unwilling to do this unless these damages were awarded by the U.S. Court of Claims. When the suits against the Government came before that court, the opinions of a patent adjudication board headed by a naval officer were the basis of awards.

THE NAVY'S PART IN DEVELOPMENT OF ELECTRONIC EQUIPMENT

Following the termination of the war naval officials felt that the future of radio communications depended upon increasing the reliability and power of the three-element vacuum tube and in developing low-frequency electronic transmitters. Commercial interests could not visualize sufficient market to warrant the development of this type of equipment and were unwilling to expend further funds in that direction. In furtherance of its program to utilize continuous-wave electronic equipment for its communication system, the Navy provided hundreds of thousands of dollars to encourage commercial interests to develop such equipment. None proved sufficiently reliable, and our own research activities developed the alternating-current tube transmitter which utilized the old spark transmitters by replacing the spark gaps with electronic oscillators. Later, naval economy brought about by the agreements of the Washington Disarmament Conference forced a discontinuance of support to commercial companies. Fortunately, by this time, the radio broadcast boom had hit the country, and it became lucrative for them to continue their research and development.

U. S. NAVAL RADIO OPERATIONS DURING WORLD WAR I

In the operating field the Navy became the sole agency, with the exception of U.S. Army field communications, for providing U.S. radio communications, both military and commercial, from the date we entered the war until 1 March 1920. Much was done during this period to increase the reliability of long-range communications by encouraging the development of higher powered arcs and alternators and by the Navy's own design of heterodyne and neutrodyne receivers, multiple-stage amplifiers, and other ancillary apparatus. By the end of the war, sufficient progress had been made in the development of static-reducing balanced antenna systems, together with improvements to transmitters and receiving equipments, to insure reliable transatlantic radio communications.

THE NAVY'S ROLE IN PROTECTING NATIONAL INTERESTS

The administration of President Wilson advocated Government ownership of public utilities, and Secretary of the Navy Josephus Daniels was a firm advocate of Government ownership of radio communications and did all in his power to achieve this, but the Congress thwarted his plans. Naval officers were instrumental in interesting the General Electric Co. in forming an American operating company, the Radio Corp. of America, for the purpose of eliminating a determined British endeavor to control this medium on a worldwide basis. Naval officers were also instrumental in bringing about cross-licensing agreements between the principal patent holders which resulted in improvements to vacuum tubes and other components. They also endeavored to make the tube freely available to all purchasers but were opposed in this by the ex-Marconi faction of the Radio Corp. of America, and it was not until it became evident that the new company was embarking on a monopolistic career that the Government took effective means to ensure the generalized use of patents on an equitable royalty basis.

NAVAL RADIO RESEARCH

At the beginning of this period the only radio research activity of the Navy was the naval radio research activity, at the Bureau of Standards, headed by Dr. Austin. Prior to the advent of the war in Europe the Radio Test Shop was established at the Washington Navy Yard for the purpose of designing naval receiving equipment and testing the equipment of commercial manufacturers. This unit did much to bring about improvements in receiver design, and their equipments were duplicated commercially and sold under several manufacturers' trademarks. Following the outbreak of hostilities, several small temporary laboratories were established for the purpose of conducting studies of static-reducing antenna systems.

After our entry into the war it was decided to strengthen our naval air arm materially. The Naval Aircraft Radio

Laboratory was established. In conjunction with the Radio Test Shop, this Laboratory did much to improve aircraft radio plants and to reduce the noise made by aircraft in flight.

In 1923 these activities were consolidated in the Radio Division of the newly established Naval Research Laboratory at Anacostia, D.C., under Dr. A. Hoyt Taylor. Here, the work of improving aircraft radio communications was successfully continued. Additionally, the Research Laboratory was assigned the task of developing the use of higher frequencies for naval usage. This was accomplished, and equipment for this purpose was designed and constructed by Taylor and his associates. While engaged in this task the phenomenon of radio echoes was first noted. Although not developed until several years later, credit goes to Taylor as its discoverer.

THE RADIO DIRECTION FINDER

The radio direction finder patents of Dr. Frederick A. Kolster were obtained in 1916 and, with his assistance as a consultant, the radio shop of the Philadelphia Navy Yard adapted them to meet shipboard requirements. These equipments were quickly fitted in most of our men-of-war. They were especially useful in destroyers for hunter-killer and convoy operations. The equipment was made more useful by Dr. Austin's development of an antenna system which made it possible easily to eliminate reverse bearings. During the war direction finder equipments were installed around the seaward approaches to the important harbor of Brest, France, where they were utilized to determine enemy submarine positions for the purposes of taking offensive action and rerouting convoys to safer entry courses. At the completion of the war, groups of direction finder stations were being erected around the approaches to our important ports. For years thereafter these stations rendered services to all mariners and eliminated delays due to reduced visibility.

DEVELOPMENT OF RADIO CONTROLLED OBJECTS

During the war the Government became interested in the development of radio controlled torpedoes and radio-guided aircraft.

The first of these was developed by Mr. John Hays Hammond, Jr., and this project was, at first, supported by the Coast Artillery Corps, U.S. Army, assisted by the advice of naval officials. After the war the Army became convinced that there was no further requirement for such a weapon. The project was then taken over by the Navy and ultimately carried to a successful conclusion.

The idea of radio guided, missile-carrying aircraft was first suggested by Dr. Peter Cooper Hewitt. The Sperry Gyroscope Co. undertook its development with the financial support of Dr. Hewitt. It quickly became evident that the program would be extremely costly and, at the suggesting of the Naval Consulting Board, it was taken over by the Navy during World War I. Little progress was made during the early stages of the problem. However, after suffering many setbacks, it did result in the development of the drone, predecessor of flying missiles.

UNDERWATER SOUND DETECTION RESEARCH AND DEVELOPMENT

The German submarine menace was sufficiently great at the time we entered World War I to make questionable our capability of providing Allied ground forces with the necessary logistic support.

Underwater sound signaling had been developed by the Submarine Signal Co. during the first decade of this century. The equipment for this purpose was of short range and required a transmitted signal of much greater intensity than the noises emitted by submarines. Numerous laboratories were established by the Navy to conduct research and development of satisfactory devices. Considerable success was achieved in developing short-range acoustical devices but these were not capable of being operated at the speeds required for tracking and destroying submarines. Towards the end of the war electronic devices were being developed. Following the war, the Navy continued this research and quickly developed an echo ranging device for obtaining soundings. In 1923 a Sound Research Division was established as a part of the U.S. Naval Research Laboratory where, under the directions of Dr. Hayes, the echo ranging device was developed into the Sonar of World War II.

THE NAVY'S ROLE IN THE EXPANDED RADIO WORLD

Improvements of the wartime low-powered voice modulated transmitter resulted in the "broadcast boom" in late 1921. Radio became an American household word. Its uses expanded rapidly and necessitated the establishment of a strong Federal radio control which eventually resulted in the establishment of the Federal Communications Commission. This body took over the licensing function of the Department of Commerce and to a large extent began controlling internal radio policy. Under the conditions which arose, the Navy's use of the radio soon became less important nationally than did that of commercial interests. Naval personnel contributed by agreeing to avoid the use of broadcast frequencies in areas where such use would create interferences. With a lucrative market for equipment, the commercial companies resumed their research, development, and design functions. Navy research personnel gradually assumed their proper role of providing guidance in the development of equipment fitted to naval needs.

EPILOG

During most of the decade the Navy was the sole U.S. agency forcing the development of radio and protecting our national interests. Only by its support of commercial manufacturers during a period of intense patent litigation, by its honest efforts towards solving the patent problem, and by its protection of national interests, could the broadcast era have arrived in this country by 1921. In fact, most of the early household radio receivers were "chinese copies" of receivers which had been designed and developed by naval personnel. Early broadcast transmitters used the techniques developed for or by the Navy during World War I. Succeeding chapters relate in greater detail the Navy's role during this important period.

CHAPTER XVII

Radio Equipment Improvement During Neutrality Period

IMPROVEMENT PROGRAMS

The Bureau of Steam Engineering promptly set about to correct the material deficiencies brought to light by unsatisfactory long-distance communications during the Mexican incident. Despite continued effort to obtain satisfactory equipment, the radio industry could not or would not expend the funds necessary to develop sufficiently rugged equipment for naval use. The superiority of undamped over damped wave transmissions had been conclusively demonstrated but receivers for the latter type were not reliable. In fact such receivers might be described as temperamental and, therefore, not satisfactory for shipboard use. Following an analysis of the situation, two programs were evolved. The first was designed to provide the earliest possible maximum improvement to existent installations by utilizing new components and techniques; the second; a long-range one, was for the eventual replacement of undamped wave by damped wave equipment.

ESTABLISHMENT OF A NAVAL RADIO DESIGN GROUP

It was decided that, insofar as possible, the Bureau would provide the design and rigid specifications for future procurements of radio equipment and, if commercial manufacturers were unable or unwilling to meet the specifications, the Navy would manufacture its own equipment. To carry out this decision additional civilian radio engineers, paid by and responsible only to the Navy, would be required. Six additional civilian aids, each an authority in a particular component of radio apparatus, were employed. They were detailed to various navy yards which were made responsible for the improvement of the components for which the assigned aid was the qualified expert. These assignments were as follows:

Navy Yard	*Expert Radio Aid*	*Responsibility*
Boston, Mass.	Mr. Walter Chadbourne	Keys; condensers.
Philadelphia, Pa.	Mr. E. D. Forbes	Antenna design and construction; rotary spark gaps; radio direction finders.
Brooklyn, N.Y.	Messrs. Guy Hill, George Lewis, and Lester Israel.	Frequency changers.
Washington, D.C.	Messrs. George H. Clark, Lester Israel, W. H. Preiss, and C. Carpenter.	Receivers; detectors; amplifiers; frequency-meters; transformers.
Norfolk, Va.	Mr. H. E. Hallborg	Reactances.
Mare Island, Calif.	Mr. George Hanscom	Transformers; quenched gaps; motor-generators.
Puget Sound, Wash.	Mr. W. H. Marriot	None.[1]

[1] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., George H. Clark, "Radio in War and Peace," pp. 113–119.

In establishing this group the Bureau of Steam Engineering, in its "Plan for Coordination of Work at Navy Yards," issued 15 June 1915, stated:

> The success or failure of the Bureau's project for government manufacture and government development of radio apparatus rests largely upon the personal qualifications of those men as regards both ability and effort, and upon the Bureau's intimate knowledge of the same . . . Recognition of the individual character of the work performed should prove a strong incentive to increased effort.

Before relating the achievements of this organization it is fitting that tribute be paid to its organizer Lt. Commdr. A. J. Hepburn, USN. This can be best done by quoting the writings of George H. Clark, his subordinate and close personal friend:

> Design, manufacture, operation! For the smooth building of a military system to handle the first, chief praise goes to Lieutenant Commander A. J. Hepburn, whose clear, incisive thinking led to the building of a smoothly-working technical corps which was operative from its very start.[2]

Hepburn completed his tour of duty in the Bureau at the time these additional civilian experts were employed and was relieved, in April 1915, by Hooper who had returned from his assignment as an observer of radio activities in the European war zone.

With responsibility for the component parts of radio equipment divided among the various navy yards, a standard drawing number system was devised by Mr. Guy Hill.[3] This was approved by Hooper and placed into effect on 15 June 1915. To prevent duplication of effort and to ensure knowledge concerning equipment available, one feature of the system required the provision of copies of each yard's blueprints to all other yards.[4]

[2] Ibid., p. 92.

[3] The details of the standard drawing number system are contained in appendix H.

[4] "Radioana," op. cit., Clark, "Radio in War and Peace", pp. 113–114.

OBSTACLES TO NAVY DESIGN OF RADIO EQUIPMENT

In May 1913 the Bureau stated its position concerning radio patents;

> . . . it could not take cognizance of patents. It must have certain apparatus and must go on buying it from whomever can or will supply it until it is informed by the Department of Justice or some other authority that we must stop it.[5]

Regardless of this official expression of policy made by the Head of the Radio Division, all Navy contracts for radio equipment continued to carry a clause requiring the supplying firm to guarantee defense against patent infringement actions. The Bureau was fully aware that the manufacture of equipment by the Navy would place it in the position of having to defend itself against any infringement actions which might be brought before the U.S. Court of Claims. The major obstacles standing in the way of manufacture were the Marconi four-circuit tuning and the Fessenden heterodyne patents.[6]

Dr. Louis Cohen who, while associated with the National Electric Signaling Co., had worked with Dr. Austin in the formulation of the Austin-Cohen empirical formula, had devised a new means of coupling, utilizing condensers in lieu of the induction coils used by Marconi. The Navy obtained the right to the use of the Cohen patents and procured his temporary services to assist in the design of receivers.[7]

CIRCUIT DEVELOPMENTS WHICH AFFECTED DESIGN OF NAVY RECEIVERS

Before these receivers were designed, several events occurred which changed the techni-

[5] Letter, dated 20 May 1913, D. W. Todd to Wireless Specialty Apparatus Co., files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[6] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 103.

[7] Annual Report of the Secretary of the Navy, 1915, (Washington Government Printing Office, 1915), p. 267.

ques of and materially improved radio reception. On 29 October 1913 Edwin H. Armstrong filed application for a patent on a regenerative circuit, and on 20 March of the following year De Forest filed application for a patent on a similar circuit. Armstrong was granted Patent No. 1,113,-149 on his circuit on 6 October 1914. De Forest, claiming prior discovery, instituted suit against Armstrong. He was unsuccessful in his early attempts to prove this, and it was not until the case reached the U.S. Supreme Court in 1928 that a decision was rendered in his favor.

Another De Forest development, which was to effect Navy designed receivers, was first exhibited at a meeting of the American Physical Society in April 1914. This was a receiver which utilized a three-element vacuum tube as an oscillator. He called it the Ultraudion. It could be used either as a detector or in lieu of the tiny, expensive, and tempermental arc that Fessenden utilized to produce the local oscillations in his heterodyne receiver. Hepburn immediately requisitioned 34 of them.[8] The "tikkers" provided by the Federal Telegraph Co. for chopping the continouus wave signals generated by the arc transmitters were discarded as rapidly as funds would permit the purchase of additional Ultraudions.

RADIO TELEPHONY DEVELOPMENTS AND THEIR EFFECT ON NAVY DESIGNED RADIO RECEIVERS

A letter, dated 22 May 1915, signed by Rear Adm. Robert Griffin,[9] USN, who had relieved Cone as Chief of the Bureau of Steam Engineering, advised the commandants of the navy yard, Mare Island, Calif.; the naval station, Honolulu, Hawaii; and the radio officer, Canal Zone, of the arrangements for conducting tests of "certain radio apparatus of novel design at the Arlington station about 15 June 1915." No details of these tests were given, the Bureau explaining:

> Without going into details, the point may be sufficiently emphasized by stating that the tests could not be held if it should prematurely transpire that the proprietors of the system are interested in radio matters, or that any test of apparatus made by them is contemplated. The Bureau has taken steps to insure that in the work of preparation for the test, including all correspondence on the subject up to this time, knowledge of the plan in view shall be restricted to the fewest persons possible, and that all such persons may be personally identified.
>
> The Bureau requests that a competent officer at each of the stations mentioned be assigned to supervise the tests and that all necessary facilities for the same be afforded. The Bureau desires not only to provide every convenience for a trial of the apparatus under the most favorable conditons, but also that a positive effort to assist should be made, freely offering such advice. services or use of special naval apparatus as the circumstances may suggest. The commercial representative is in immediate charge of the test and all technical details of the apparatus in question. It will probably be impractical to confine knowledge of the test and of technical details to a single naval representative at each station but every effort should be made to restrict this knowledge to the fewest persons possible.

Proprietor's representatives were authorized, upon producing a copy of the referenced letter, to assist at the cooperating stations as follows: Messrs. R. L. Hartley and B. W. Kendall, Mare Island; Lloyd Espenschied, Honolulu; and R.H. Wilson, Colón.

The instructions contained in this letter paved the way for the first long-distance radio telephony tests. These followed, within a few months, the inauguration on 25 January 1915, of transcontinental wire telephony, made possible by the development of a satisfactory repeater system using the De Forest triode.

The American Telephone and Telegraph Co., the proprietors, constructed a temporary building to house their trans-

[8] Ibid., p. 105.

[9] Griffin was born in and appointed a cadet engineer from Virginia. He graduated from the Naval Academy in 1847. He became Chief of the Bureau of Steam Engineering in 1915, with the rank of rear admiral, and served in this capacity until his retirement on 27 Sept. 1921. He died 21 Feb. 1933.

mitting equipment close by the transmitter building at Arlington. Switching arrangements were installed in such a manner as to allow the huge Arlington antenna to be shifted to their transmitting equipment whenever it could be spared. This equipment consisted of "a microphone circuit and an oscillating vacuum tube circuit fed into a modulator tube, which in turn was connected to a single stage of amplification supplemented by a second stage with a large number of tubes in parallel. These amplifier tubes were about 50 watts each in power rating." [10] The company representatives carried special receivers to the stations to which accredited. In the tests there were no efforts to establish two-way radio telephone communications, the return circuits from the receiver being by cable and telephone.

Arlington released the antenna to the Telephone Co. whenever possible, which was not often. When the transmitter was in use the most common and monotonous occurrence was the burning out of a tube in the second amplifier stage. Despite all the difficulties and annoyances, long-distance records were established and naval and military officials who observed the tests were highly impressed. The station at Darien, C.Z., distant 2,100 miles, received voice transmissions on 27 August, and both voice and music 2 days later. The Mare Island station, distant 2,500 miles, was able to receive the transmissions on 29 September and on the following night they were received by Espenschied at the Honolulu station.[11]

Following these successes attention was turned to Paris where, with the cooperation of Lt. Col. Ferrie, head of the French Military Communication System, the Eiffel Tower antenna was made available. France being at war, the antenna could only be used for test purposes at rare intervals, which were usually of only a few minutes' duration. This, coupled with the necessity of advising Arlington when to transmit by deferred cable service, made the tests a laborious and tedious procedure. On 23 October transmissions were received at Paris, distant 3,600 miles.[12]

During the tests much information was obtained concerning both radiotelephony and radiotelegraphy. Clark was allowed to trace the Telephone Co. circuits, and in his words:

> . . . there he saw for the first time the arrangement for obtaining "feedback" in a circuit so as to cause an associated vacuum tube to oscillate. Simply described, this consisted of a coil in the plate circuit of the vacuum tube, which coil was coupled to the secondary receiver coil, or other coil in which oscillations were to be produced. Since variation of coupling had a direct bearing on results this at once was seen to provide a positive method for making a tube oscillate, whereas with the De Forest ultraudion scheme, which had no variables, oscillation was a matter of hit or miss.[13]

FIRST NAVY DESIGNED AND MANUFACTURED RECEIVERS

The Washington Navy Yard, responsible for design of receiving equipment, established a radio laboratory in the River Radio station, which had not been used since the establishment of the station at Radio (Arlington), Va. There, Cohen, assisted by Clark and L. G. Butte, took the best portions of the new developments and incorporated them in the designs of the Navy types "A" (60-600 kc.), "B" (30-300 kc.), and "C" (1,200-3,000 kc.) receivers. These were completed in early 1915 and placed in production at the Washington Navy Yard in the same year.[14]

The Cohen method was used. This consisted of coupling and a modified type of feedback circuit, with a coil in the plate circuit for the purpose of making the vacuum tube oscillate. To avoid the use of the term "feed-back," Clark termed it "a 'tickler' because it tickles the audion and

[10] "Radioana," op. cit., Clark, "Radio in War and Peace", p. 247.

[11] Ibid., p. 248.

[12] Ibid.

[13] Ibid., p. 106.

[14] Ibid., p. 103.

makes it quiver." [15] The leads were of solid wire capable of withstanding shipboard vibration and the shock of gunfire. The induction coils were of low resistance as compared with those used in commercial receivers and their values in the two circuits could be varied to provide sharp tuning. Dials were fixed to the shafts of the tuning condensers making it possible to calibrate each receiver so that the operator could tell where to aline it for specific frequencies. Arrangements were incorporated to permit the use of either crystal or vacuum tube detection.

These receivers were placed in service at the shore stations and on the more important combatant ships as fast as they could be manufactured. However, economy dictated the continued use of the crystal detector, and the heterodyne feature was used only for the reception of the continuous wave signals.[16]

AMPLIFIER AS AID TO RECEPTION

From the beginning of radio, engineers and operators recognized the desirability of amplifying the received signal and of improving the signal-to-noise ratio. Late in 1912, the Federal Telegraph Co., for which De Forest was then working, had delivered the Navy a crude "bread board" model of an amplifier which increased the intensity of the signal without introducing additional noises of its own. It provided sufficient amplification to allow the first daylight reception of a west coast transmission at Arlington. De Forest left the employ of the Federal Co. in 1913 and reorganized his defunct Radio Telephone Co., changing its name to the Radio Telephone and Telegraph Co. In November of that year he submitted the first sample of a commercial amplifier to the Navy for test. The following month 10 were purchased, and the use of the amplifier in radio receiving began. They were not at that time included as components of radio receivers and were used only for audiofrequency amplification. Economy necessitated limiting the supply of amplifiers to one for each ship and shore station. A switching arrangement was provided so that the amplifier could be connected to the particular receiver most in need of it. During 1914 the Navy continued to purchase them from De Forest, but they were not a completely satisfactory device and were later redesigned to meet service requirements.[17]

IMPROVEMENT OF VACUUM TUBE

Equipment utilizing the three-element vacuum tube possessed one serious weakness, the tube itself, as manufactured by the Radio Telephone and Telegraph Co. They were expensive, short lived, and lacked uniformity due to De Forest's persistent belief that some residual gas should be left in the tube. It was impossible to gage the exact amount of gas left with the result that some of the tubes were better amplifiers, and others better detectors. To limit the number carried, it was essential that each tube function equally well for all purposes. Dr. H. D. Arnold of the American Telephone and Telegraph Co. held the opinion that the instability of De Forest's tubes "was caused by gas ionization, and that this defect could be removed by increasing the vacuum." He also believed that the tube could be improved by the use of an oxide coated cathode in lieu of one of tantalum. By the end of 1913 the Telephone Co. had developed a tube with a laboratory life of 1,000 hours which could be uniformly produced. Dr. Irving Langmuir of the General Electric Co. arrived at the same conclusion held by Arnold in respect to the necessity for a high vacuum. The Bureau of Steam Engineering considered that De Forest, as the inventor of the three-element tube, should be favored in the purchase of tubes, provided

[15] Ibid.

[16] Ibid., p. 103.

[17] Ibid., p. 107.

he could deliver a product comparable in quality and cost. Despite persistent effort to convince De Forest that his theory was erroneous, he continued to deliver nonuniform tubes with high residual gas content.

At this time the Bureau took the first of many successful actions destined to improve the quality and life of tubes by making it financially feasible for industry to expend funds for research. A requisition was prepared for vacuum tubes in which the specifications called for uniform, high vacuum tubes, guaranteed for a life of 5,000 hours at a cost of $10 each. In addition to De Forest, both the General Electric and the Western Electric Cos. were urged to meet the specifications. De Forest merely laughed at the requirements. The Western Electric Co. stated that the 5,000-hour requirement could be met but that a more practical tube could be built if the life guarantee was reduced to 2,000 hours and the cost reduced to approximately $4.50 per tube. The specifications were modified accordingly, the Western Electric Co. was awarded the contract and produced satisfactory tubes. This action on the part of the Navy in placing a seemingly impossible requirement on American industry resulted in advancing the radio art in this country by at least 2 years, saved the Government thousands of dollars, and made the general naval use of tubes economically feasible.[18] De Forest continued to attempt to compete with other tube manufacturers but was never able to produce comparable tubes.[19]

IMPROVEMENT OF CONDENSERS

The high capacity condensers required for radio transmitters had necessitated the use of Leyden jars. In the earlier days these were made of glass covered with tinfoil. Later types were made of glass plated with copper. Those utilizing Bohemian glass were the best. During World War I the supply of this glass was cut off, and manufacturers were forced to resort to jars of American manufacture. In December 1914 the Wireless Specialty Apparatus Co. delivered a shipment which failed to meet Navy specifications but urgent requirements necessitated their acceptance. Jars of Bohemian glass had been a constant source of trouble but the wartime inferior product caused even more annoyance.

Early in 1916 Mr. William Dubilier submitted a mica condenser for test. It failed to meet the requirements of the Navy or to fulfil the claims of its inventor. Hill, Radio Aide at the New York Navy Yard, believed Dubilier's idea possessed merit and drew up specifications for such a device requiring, among other things, that they be in metal containers so that the generated heat could be radiated faster. By December of the same year, with Hill's advice, Dubilier had improved his product and the Bureau purchased 1,000 of them. In the meantime Firth, of the Wireless Specialty Apparatus Co., not at all happy at the prospect of losing the lucrative Leyden jar business, entered the mica condenser field and sold the Navy 750 condensers in the same month. During the next several years both manufacturers sold large numbers of these condensers. Following the war Dubilier brought an infringement action against the Wireless Specialty Co., but the suit was settled prior to court decision.[20]

NAVY RADIO TYPE NUMBER SYSTEM

By 1916 so many component parts of naval radio equipment were in stock that it became difficult to identify any specific item without long descriptive discourse. To simplify the situation, a type number system

[18] U.S. Naval Communications Division Memorandum, 10 February, 1937.

[19] U.S. Navy Contract 980, 8 May 1918, was awarded De Forest for 2,000 tubes. Because of lack of uniformity 1802 of these were rejected.

[20] "Radioana," op. cit., Clark, "Radio in War and Peace", pp. 109–110.

devised by Clark was placed in effect. In this, a modification of which is still in effect, a specific consecutive number was assigned each device and to collective components. Preceding the type number was a letter designation indicating the design source: SE if designed by the Navy, or C if of commercial design, followed by one or two additional letters indicating the particular originating company.[21] Mr. A. M. Trogner, then the chief draftsman for the Bureau, worked out the details and made the assignments.[22]

STATUS OF NAVY DESIGN AT TIME WE ENTERED THE WAR

The rapidity with which the Navy radio engineers designed the various components of radio transmitters and receivers is astounding. By the time we entered the war, 25 percent of the components of radio equipment to which type numbers had been issued were of Navy design. Nor does this present the complete picture because the percentage of commercial design was largely made up of standard electrical instruments, insulators, motor generators, condensers, etc., while those contained in the Navy's portion included many complete transmitters and receivers, and in most cases the component parts of these were mostly of Navy design. As an example, SE 720, a 5-kw. spark transmitter of Navy design, was made up of 14 Navy and 3 commercial components. CM 301, another 5-kw. spark transmitter of American Marconi design, was made up of five Navy, seven Marconi, two Dubilier and one Crocker-Wheeler components.[23]

[21] Appendix I contains a list of manufacturers designations.

[22] "Radioana," op. cit., Clark, "Radio in War and Peace", pp. 115–116.

[23] "Model Letter and Type Number Book, 1923," (RE 15A 101F), Navy Department, Washington, D.C.

INCREASED EQUIPMENT REQUIREMENTS

In August 1916 Congress authorized a $600 million program for the construction of 10 battleships, 6 battle cruisers, and 140 miscellaneous naval vessels during the next 3 years.[24] The manufacturing facilities of the various navy yards were not sufficient to provide radio apparatus in the quantities required by this preparedness program and this necessitated dependence upon commercial production. A court decision of the previous year had made the acceptance of Government contracts for radio equipment more attractive to commercial manufacturers. Judge Hough, presiding over the U.S. District Court for the Southern District of New York, had held that owners of patents infringed in the manufacture of equipment under Government contracts were limited to the recovery of damages from the United States. Manufacturers, many of them just entering the field, believing themselves secure from litigation, sought Government contracts. Competition became so intense that all were willing to provide equipment based on Navy design and meeting Navy specifications.

STANDARDIZATION OF SHIPBOARD INSTALLATIONS

Prior to the beginning of World War I shipboard installations had been made primarily on a space available basis without regard to space best meeting the particular requirements of radio. Following the authorized increase in the Navy, the Bureau, in 1916, prepared standard equipment allowances and installation plans for each type of naval vessel.[25]

[24] David Saville Muzzey, "A History of Our Country," (Ginn and Co., Boston, 1943), p. 653.

[25] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 120.

COMPARISON WITH OTHER NAVIES

At the time of the outbreak of hostilities in Europe, Germany was as well advanced in the radio field as any nation. Due to the widespread activities of the Marconi Cos. she had not been too successful in commercial exploitation, but her military equipment was superior to that of France and England. The German Navy was equipped with quenched-gap spark transmitters and Germany also had an ample number of shore stations to serve the requirements of her fleet. France had made little use of radio, but her navy was equipped. England, because of the Marconi interests, had a source of trained designers and manufacturers but, due to the nature of the envisioned operations of the Home Fleet, continued to use broadly tuned and less sensitive equipments. By the time the United States entered the war, we had better radio equipment than any other navy. The quenched-gap component of our spark transmitters, built on Navy specifications, was superior to that of Germany; Navy-designed power control units permitted limiting the output of transmitters; Navy-designed frequency changers allowed a transmitter to be quickly shifted from one frequency to any of several others; the rotary spark and the arc transmitter provided reliable communications over much greater distances; and our Navy-designed and constructed receivers were the best in the world.

CHAPTER XVIII

Development of the High-Powered Chain

AUTHORIZATION

As previously related, sufficient success in increasing radio operating ranges with the Fessenden rotary spark transmitter had been achieved by 1912 to warrant the Navy Department to request Congress to authorize and appropriate funds for a high-power chain to extend southward to the Canal Zone and westward to the Philippines. On 22 August 1912, Congress authorized $1 million and appropriated $400,000 for the construction of this chain. The authorization act stated that one station should be located in each of the following areas: Canal Zone, on the California coast, Hawaiian Islands, American Samoa, Guam, and the Philippines.[1] The Radio (Arlington), Va. station, covering the North Atlantic and under favorable conditions, and capable of communicating with the Canal Zone and the west coast in case of interrupted cable or landline communications, was the seventh of the high-powered stations.

PLANNING THE CHAIN

Originally it was intended that transmitters similar to the Fessenden synchronous rotary spark at Arlington would be used, but the performance of the Federal Co.'s arc, which gave longer ranges at less power and initial cost, resulted in changing to that type of equipment. Hooper desired to use an Alexanderson alternator at San Diego and a Telefunken frequency doubler alternator at Cavite but this did not prove feasible. The General Electric Co. could not guarantee that they could manufacture a satisfactory 200-kw. alternator and refused to sell it unless it met specifications. The Telefunken Co. submitted a bid on their frequency doubler alternator and immediately withdrew it, fearing the British would seize the vessel carrying it.[2]

With the opening of the Panama Canal in August 1914, the requirement for adequate radio communication between the Canal Zone and Washington was pressing both for defense purposes and for the administrative business of the Government. Unsuccessful attempts by Army and Navy officials to agree upon plans for a high-powered station in the area resulted in the matter being referred to the Joint Army and Navy Board in 1911. This Board's recommendations, which were approved by the President, prohibited private or commercial stations in the Canal Zone and authorized the Navy to install, maintain, and operate a high-powered radio station there to be used in conjunction with other naval radio stations in the Atlantic and Pacific and for controlling the movement of the fleet in waters adjacent to the canal. The Board recommended that all radio

[1] "Naval Appropriation Laws from 1883 to 1912," Navy Year Book 1912, Woodbury Pulsifer (Washington, Government Printing Office, 1912), p. 718.

[2] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., G. H. Clark, "Radio in War and Peace," p. 241–242.

stations in the Canal Zone transmit and receive commercial traffic.[3]

Following the successful demonstration of the arc transmitter at Arlington, Hepburn ordered ten 30-kw. transmitters for shipboard use and, on 30 June 1913, contracted for one 100-kw. for installation in the Canal Zone station. The Federal Telegraph Co. accepted this contract at the Navy's risk, claiming that such a huge device, three times more powerful than any they had previously constructed, would generate excessive heat and would never be satisfactory.[4]

CONSTRUCTION OF THE CANAL ZONE HIGH-POWERED STATION

Following the President's approval of the recommendations of the Joint Army-Navy Board, a site was selected at Darien, 25 miles south of Colón. Construction was begun in December 1913 by the Quartermaster Department of the Panama Canal. All buildings were constructed of concrete, and the arc and receiving rooms were completely shielded by means of bonded and grounded wire mesh imbedded in the concrete. Three 600-foot, self-supporting, grounded steel towers located at the apexes of an approximately equilateral triangle, each side measuring about 900 feet, were erected to support the three sections of a flattop antenna. The completion of the station was delayed by the delinquency of the tower contractor, but it was finally placed in commission on 1 July 1915. The total cost was approximately $400,000. With the exception of minor and easily eliminated defects, the 100-kw arc immediately provided a signal easily received at Arlington except during the worst static periods. The Federal Telegraph Co. receivers, with tikkers, were supplemented by Navy designed heterodyne receivers.

[3] R. S. Crenshaw, "The Naval Radio Stations of the Panama Canal Zone," U.S. Naval Institute Proceedings, 1916, p. 1209.

[4] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 234.

CHANGES IN PLANNING FOR OTHER STATIONS OF THE HIGH-POWERED CHAIN

The cost of the Darien station made it evident that the $1 million authorized for the construction of the high-powered chain was insufficient. Congress increased the authorization by another half million dollars on 3 March 1915, providing a total of $1,500,000 for the construction of five stations. Based upon previous plans, this amount was still insufficient. The successful operation of the Darien transmitter with its increased range and improvements in receiving, brought about by the use of the heterodyne receiving method used with the three-element vacuum tube as an oscillator and as an amplifier, made it possible to change the plans. It was decided to equip Pearl Harbor and Cavite with 350-kw. arc transmitters capable of direct communications with each other, thereby eliminating the requirement of relaying through Samoa and Guam. At these locations 30-kw. arc equipments would be installed in the existent buildings and the antennas would be improved to provide sufficient radiation.[5] The Federal Co. had refused to guarantee the 100-kw. arc for Darien. When asked to construct the 200-kw. for San Diego and two 350-kw. ones for Pearl Harbor and Cavite, they were horrified, and again the Bureau had to gamble that they would be successful.[6] The contract for these was signed on 21 February 1916.

COMPLETION OF THE HIGH-POWERED STATIONS

Sites were selected for the three stations but a title flaw in the property selected in California, the only one in the chain for

[5] Annual Report of the Secretary of the Navy, 1915 (Washington, Government Printing Office, 1915), pp. 6–7.

[6] "Radioana," op. cit., Clark, "Radio in War and Peace," pp. 241-242.

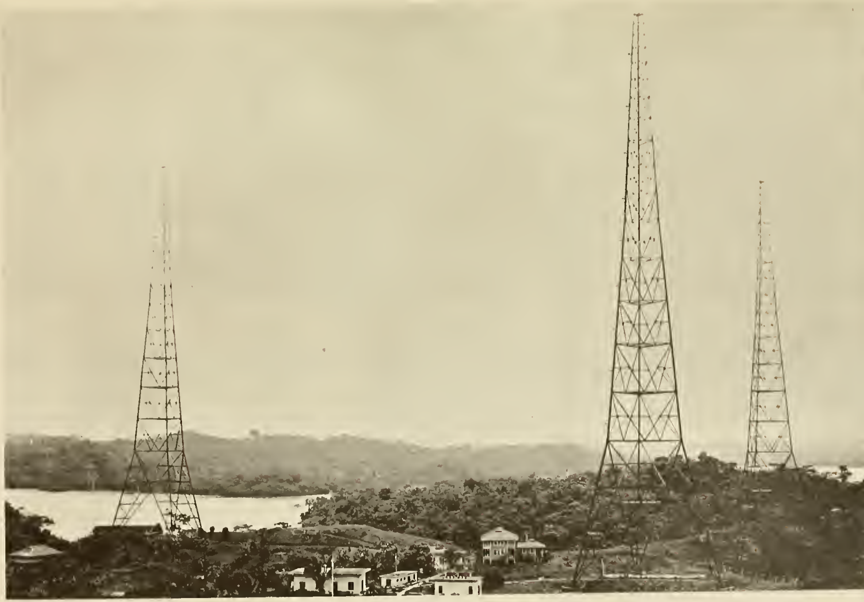

FIGURE 18–1. U.S. Naval Radio Station, Darien, C.Z., 1915.

which private property had to be acquired, caused some delay. Since it was desired to effect savings by placing a single contract for the towers of the three stations, this necessitated delaying all work. About the end of October 1915, proposals for tower construction were advertised. The plans for all three stations followed the basic layout of Darien, with departures to fit the terrain and with the distances between towers increased wherever possible.

The San Diego station was the first to be completed. Although it did not go into commission until May 1917, the official trials commenced on 26 January when Hooper sent the first message to Arlington using a silver key especially prepared for the occasion.[7]

San Diego made quite a celebration over the completion of this station which presented an imposing sight with its three 600-foot towers crowning the hills across the bay from the city. On the day before the commissioning ceremony, everything went wrong, and there was a question as to whether the transmitter could be used because of a faulty keying circuit. One of the events was to be the transmission of a message from the new station to the Secretary of the Navy, and the receipt of his reply by the remote receiving station in San Diego. Hooper, not desiring that the Navy be held in ridicule by the possible failure of the transmitter, telegraphed the Bureau the message he intended to transmit and requested an advance copy of the Secretary's reply be wired him at once. The next morning brought no response. With great trepidation he joined the mayor, the city council, and other local dignitaries for the trip to Chollas Heights. On arrival at the station he discovered that the reply to his message had been delivered there. He could go through the motion of transmitting and then, after a proper time, he could deliver the press a message from the Secretary. He breathed a sigh, a very quiet sigh, of relief. The hour appointed for the station's first official transmission arrived. Hooper took his seat at the keying position and began transmitting his message. To his astonishment the huge relay key obeyed the commands of its tiny counterpart, and the transmitter was on the air. The Federal engineers, assisted by the station personnel, had labored long into the night checking and rectifying, rechecking and testing. One minute passed with no reply being received. Two minutes passed and then the operator, connected by wire line to the receiver at the remote receiving station, commenced writing. In another minute he handed Hooper a folded message which he, in turn, handed the mayor for that dignitary to read aloud to the assemblage. As the mayor read, Hooper secretly checked it with the advance copy. Wily Secretary Josephus Daniels had added an additional question which required a reply.[8]

Upon his return to Washington, Hooper was directed to the Secretary. As he stepped into that dignitary's office he was greeted with the remark: "That was trickery, Hooper! I didn't like it at all!" The expected reply of "Aye, Aye, Sir" was received, and the incident was closed.[9]

Meanwhile, construction of the stations at Pearl Harbor and Cavite was proceeding. The war caused delays in the fabrication of the towers and those for Cavite were further delayed by the British seizure of the ship carrying them. The towers were finally released after prolonged diplomatic negotiations. Pearl Harbor was placed in commission 1 October, and Cavite on 19 December 1917.

The transpacific chain was completely successful but its construction had necessitated overcoming many obstacles and the taking of numerous calculated risks. Both Austin and Clark had claimed that the antenna voltages would be more than exist-

[7] The Electrical World (McGraw-Hill Publishing Co., New York), vol. 59, No. 10, 6 Mar. 1912, p. 429.

[8] "Radioana," op. cit., Clark, "Radio in War and Peace," pp. 229-230.

[9] Ibid.

ing insulators could withstand and that the corona would prevent efficient radiations. When the Federal Co., submitted a plan requiring chains of interlocked porcelain insulators, each approximately 15 feet long and at a total cost almost equal to that of the transmitter, Hooper asked the Locke Insulator Co. to design a practical strain insulator for the purpose. To the great credit of this company, then a small concern, they developed, within a few months, a practical insulator with metal corona shields which could be installed on the wings of the towers.[10]

TRANSATLANTIC HIGH-POWERED STATIONS

Following the outbreak of World War I the President, by Executive order, directed the Secretary of the Navy to take over "one or more high-powered radio stations within the jurisdiction of the United States and capable of transatlantic, communication." [11]

In compliance with this order, the high-powered station at Tuckerton, N.J., was taken over on 9 September. This station, completed just prior to the beginning of the war, was constructed by the German firm Hochfrequenz-Machinen Aktiengesellschaft für Drahtlose Telegraphie, commonly known as the Homag Co., for the Compagnie Universelle de Télégraphie et Téléphonie of France. The Homag Co., on one pretext or another, had withheld the station from the French. The American subsidiaries of both companies had applied for licenses to operate, but, with ownership in dispute, these applications had been denied.[12]

The station was equipped with a Goldschmidt 100-kw., high-frequency, reflection-type alternator and utilized an umbrella antenna. Shortly after the Navy assumed control some of the armature coils burned out. A court of inquiry was convened which held the accident not due to the fault of negligence of any person in the naval service. The Navy Department took immediate steps to install a 30-kw. Federal arc transmitter. This installation was completed by 27 October and, by crowding, it could, under normal conditions, be heard by the German station at Eilvese, distance 3,382 nautical miles. This transmitter was replaced shortly thereafter by a 60-kw. arc, powered by a General Electric Co. 500-volt, direct-current, railroad-type generator. Its transmissions were received by Eilvese continuously except during the heavy static season.[13] In the meantime the Homag Co. procured another Goldschmidt alternator from Germany which was placed in service early in 1915. After the installation of this second alternator it was used in rotation with the arc. Confirmation of messages indicated the arc to be slightly more reliable.[14] In the latter part of 1916 the 60-kw. arc was moved to Arlington where it was urgently required. The Homag Co. then installed another 60-kw. arc which they leased from the Federal Telegraph Co.[15]

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[10] Ibid., pp. 242–245.

[11] Executive order of the President of the United States of America, No. 2042, dated 3 Sept. 1914.

[12] Annual Report of the Secretary of the Navy, 1915 (Washington, Government Printing Office, 1915), p. 264.

[13] Ibid., p. 265.

[14] Ibid., "Radioana," op. cit., Clark, "Radio in War and Peace," p. 262, footnote states: "The first breakdown of the alternator, late in 1914, was repaired in the United States. The alternator broke down again on Jan. 24, 1915, and was left in that condition." This is in variance with the annual report of the Secretary of the Navy, 1915. It is assumed that the Secretary's report was compiled from official sources. Clark fails to reference his source and it is believed that he was writing from memory. Additionally, on p. 276 of the same manuscript, he states: "After the alternator was replaced in February of 1915, night schedules alternating hourly between the arc and alternator, were maintained, but, as the station records graphically show, the percentage of successful reception was so much greater with the arc that in time it was the only transmitter used. The alternator was relegated to a weekly test to keep it in running shape."

[15] " Radioana," op. cit., Clark, "Radio in War and Peace," p. 276. This lends credence to Clark's statement quoted in the previous footnote.

Prior to the war, the Atlantic Communication Co., an American subsidiary of the German Telefunken Co., had constructed, obtained a license for, and was operating a high-powered radio station at Sayville, Long Island, in conjunction with a sister station at Nauen, Germany. It had originally been equipped with a spark transmitter but in 1914 its owners desired to increase its power. New towers were erected and a new antenna system was installed. The spark transmitter was replaced by a 100-kw. Telefunken alternator. The Secretary of Commerce deemed the act of increasing the power equivalent to the construction of a new station, an act prohibited by the Hague Convention of 1907, to which the United States was a signatory power. On the admitted evidence that the majority of the stock of the Atlantic Communication Co. was owned by the nationals of a belligerent country, the company was refused a license. In order not to leave the station idle, the Navy Department, on 9 July 1915, took over its control in accordance with the Executive order of 5 September 1914 and utilized it to communicate with Nauen.[16] For the next 20 months it was operated by the Navy as a commercial station. In 1916 its revenue was almost $1-million. After the entry of the United States into the war it was deemed the property of enemy nationals and title to it was turned over to the Navy Department by the Alien Property Custodian.[17]

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[16] Annual Report of the Secretary of the Navy, 1915 (Washington, Government Printing Office, 1915), pp. 266–267.

[17] "History of the Bureau of Engineering, Navy Department, During the World War" (Washington, Government Printing Office, 1922), p. 94.

CHAPTER XIX

Operations and Organization of United States Naval Radio Service During Neutrality Period

SERVICES RENDERED BY NAVAL RADIO SERVICE

In addition to handling Government radio messages, the Naval Radio Service maintained continuous watches at all naval shore radio stations on the international calling frequencies of 500 and 1,000 kc. for the purpose of guarding distress signal transmissions and handling press and commercial traffic in areas not adequately serviced by commercial companies. To aid in the safety of shipping, periodic time, weather, and hydrographic broadcasts were made by the several stations on each coast. Ships, passing within radio communication range of a naval shore radio station, could obtain direct weather and hydrographic information upon request. The stations at Arlington and Key West broadcast press daily at 2030 zone plus five time. This was provided through the courtesies of the Associated Press, which compiled it at New York, and the Western Union Telegraph Co., which transmitted it simultaneously to Arlington and Key West. Merchant vessels at sea could report their positions to the nearest naval radio station, and naval vessels were required to do so. Reports of these positions were compiled and furnished daily to the leading newspapers of the country.[1]

[1] Annual Report of the Secretary of the Navy, 1915. (Washington, Government Printing Office, 1915), p. 282.

NEUTRALITY CENSORSHIP

The immediate effect of the war upon the Naval Radio Service resulted from this country's determination to maintain its neutrality. Upon the outbreak of hostilities in Europe, President Wilson issued a proclamation on neutrality as relates to wireless, dated 5 August 1914. This proclamation, the enforcement of which was delegated to the Secretary of the Navy, prohibited radio stations within the jurisdiction of the United States from transmitting or receiving for delivery messages of an unneutral nature and from in any way rendering to any one of the belligerents any unneutral service. The Secretary further delegated this responsibility to the Superintendent of the Radio Service.

Instructions for enforcing the Executive order were issued to all Government, private, and commercial radio stations, and to all radio operating companies. Censors were stationed at the stations at Sayville, South Wellfleet, Siasconsett, Belmar, and Miami. District commandants were charged with insuring that private stations understood the contents of the Executive order. In one naval district all amateur stations were closed to the transmission of messages of any character for a time sufficient to impress upon their owners the necessity of keeping their transmissions to a minimum.[2]

The "Censors' Instructions" prohibited

[2] Ibid., p. 272.

the transmission or receipt of cipher or code messages between radio stations in the United States, its territories or possessions, and stations of a belligerent, and the relay of such messages through a station of another neutral. No messages could be handled which contained information relating to the operations, personnel, or material of the armed forces of a belligerent, except enciphered messages between U.S. Government officials.

All operating companies except the Marconi Wireless Telegraph Co. of America accepted the conditions imposed upon them and many issued supplementary instructions. On 12 August 1914, John W. Griggs, president and general counsel of the American Marconi Co. addressed a telegram to the Secretary of the Navy questioning the validity of the "Censorship Instructions." The Secretary replied the following day:

> If you will send representatives to Washington will be glad to take up before Attorney General questions of law relating to the censorship of wireless messages by Navy Department under Executive order of the President dated August 5th.

Griggs replied on 19 August declining to discuss the issue before the Attorney General, but he included in his letter a brief stating his company's position against censorship.

On 2 September the Marconi station at Siasconsett accepted and forwarded, without referring it to the censor, a message from the British Cruiser *Suffolk*, addressed to an individual in New York, requesting supplies be delivered off Sandy Hook. The Navy Department considered the handling of this message by a station in the United States an unneutral act and requested an explanation on the same day the message was transmitted. Mr. Griggs replied on 9 September, stating that he was advised that the message in question was not in violation of any law of neutrality; that he did not consider the Navy Department had legal authority to prohibit such traffic; that the censor violated the Communications Act of 1912 in forwarding a copy of the message to the Navy Department; and that the Navy Department "had no right nor power" to close the station.[3]

The Marconi interests then endeavored to test the validity of the authority vested in the Secretary by the President's Executive order by seeking an injunction in the U.S. Court preventing the Secretary or his agents from interfering with the transmission of messages through any of their stations. This suit was dismissed by the court because of lack of jurisdiction. No attempt was made to bring the matter before a higher court, and with the company's persistent refusal "to recognize the right of censorship" and failure to provide explanation for accepting and forwarding the H.M.S. *Suffolk* message, the Navy Department, on 24 September 1914, ordered its censor to close the Siasconsett station to the transmission of all radio messages. The station remained closed until 16 January 1915, when authority was granted to resume business.[4]

On 1 January 1915 the restrictions, which were working some hardships upon those sending purely business or personal messages, were relaxed by the issuance of new instructions. This was made possible by the Government taking control of the commercial station at Tuckerton, N.J., and requiring that all questionable messages be handled by that station.

Ships of belligerent countries were prohibited from using radio while in United States waters and the radio apparatus of such ships was sealed by customs officials, and in some cases antennas were lowered and disconnected.

After the *SUFFOLK* incident, no further violations of neutrality by commercial companies occurred. However, there were many reports, from all parts of the country, of unauthorized radio stations, established solely for the violation of neutrality. Investigation of each individual report failed

[3] The Wireless Age, Sept. 1914, pp. 964–966.

[4] Annual Report of the Secretary of the Navy, 1915, op. cit., p. 273.

to indicate the existence of a single such station.[5]

The final report upon neutrality censorship, which ceased upon our becoming a belligerent, stated ". . . it is gratifying to report that owners of commercial stations have during this fiscal year, generally cooperated loyally with the Government in maintaining the neutrality of the United States." [6]

OPERATION OF THE TUCKERTON AND SAYVILLE STATIONS

Early in the war the British severed the cables to Germany and that country was forced to rely upon radio communications in the conduct of commercial and diplomatic business with other nations. To provide a U.S. terminal for a circuit with European countries, the station at Tuckerton, N.J.,[7] was taken over and operated by the Navy for the U.S. Government.[8] The operation of this station was limited to transmitting or receiving messages from shore stations in Europe and the United Kingdom. Official messages of United States and foreign government officials were given priority over commercial or press messages. No messages in code or cipher were transmitted or received for delivery unless the Navy operating personnel were provided with the means of decoding or deciphering them. No messages in unintelligible terms or foreign languages were acceptable unless translations were provided which satisfied the official censors. The naval censors at the station were responsible for insuring that no messages of unneutral character were handled. Addresses were required to be in plain language and to be at least four words in length with a signature of at least two words. No message could be transmitted or delivered until countersigned by a censor. The Navy accepted no responsibility for delivery. The station charge was 25 cents per word, cable count, without minimum.[9]

Although available for operations with any European or United Kingdom station the only one with which traffic was exchanged was Eilvese, Germany. The Homag Co., was allowed to maintain the station and was duly paid for this upon certification of expenses by that company's agent and the naval officer in charge. All revenue in excess of maintenance was held in trust by the Navy Department pending adjudication of rightful ownership. Between 27 October 1914 and June 30, 1915, 13,789 paid messages were transmitted for which Tuckerton's net income was $38,929.47.[10]

On 9 July 1915 the Navy took over the Atlantic Communication Co. station at Sayville, Long Island, and commenced operating it under the same conditions as prescribed for Tuckerton. This station operated on schedules with its sister station at Nauen, Germany. Since there was no question of ownership, revenues received were given over to the owners who performed the accounting, forwarding copies of all messages and accounting forms to the Superintendent, U.S. Naval Radio Service, for comparison and checking.[11]

MOBILIZATION OF COMMUNICATION RESOURCES

On 4 February 1915, the Germans issued a proclamation declaring the high seas around the British Isles an unrestricted war zone and warned neutral vessels of the dangers of entering the area. On 7 May 1915, the *S.S. Lusitania* was torpedoed and sunk, 10 miles off the southern coast of Ireland, with a loss of life of 1,198 men, women and children, 128 of whom were Americans. Repeated exchanges of notes revealed the ada-

[5] Ibid.

[6] Annual Report of the Secretary of the Navy, 1916, (Washington, Government Printing Office, 1916), p. 27.

[7] Infra, ch. XVIII.

[8] Annual Report of the Secretary of the Navy, 1915, op. cit., p. 265.

[9] Ibid., p. 290.

[10] Ibid., p. 266.

[11] Ibid. pp. 266–267.

mant attitude of the German Government. The clamor for increased preparedness raised by the American public resulted in enormously increased military appropriations. In March 1916, the French S.S. *Sussex* was sunk in the English channel with loss of two American lives. President Wilson immediately notified the German Government that diplomatic relations would be severed unless she immediately forswore and abandoned her methods of submarine warfare against neutral shipping. This brought forth a German promise that it would not sink merchant ships without warning and without attempting to save lives.

The *Sussex* incident increased the efforts of the Navy Department to ensure that, among other things, the U.S. Naval Radio Service be brought to a peak of readiness and efficiency. To determine the wartime capabilities of the United States, a mobilization of communication facilities was ordered. Mr. Theodore N. Vail, President of the American Telephone and Telegraph Co., in a letter dated 19 April 1916, stated, ". . . we would take a patriotic satisfaction in placing our system at the service of the Government in any time of need . . ." [12]

This mobilization was ordered for a 40-hour period which began at 1600, Saturday, 6 May 1916. Telegraph and telephone connections were made between the Navy Department and all navy yards and naval radio stations in the United States. A radiotelephone transmitter that had been installed at Arlington for long-distance radiotelephony tests was still at that location. Another smaller transmitter and one of the receivers used during the above-mentioned tests were installed in the U.S.S. *New Hampshire*, Capt. Lloyd N. Chandler, USN, commanding. The *New Hampshire* was to be in the vicinity of Hampton Roads during the mobilization tests. Another one of the receivers was installed at the Norfolk Naval Radio Station.

[12] The Telephone Review, (house organ of the American Telephone and Telegraph Co.), May 1916.

Two-way radiotelephone communications were established immediately upon commencement of the test and were maintained at will with the *New Hampshire* via wirelines to the Norfolk Naval Radio Station, thence by radio to the ship, and by radio from the ship to Norfolk, thence by wireline to the Navy Department or other stations. On 7 May Captain Chandler, at sea off the Virginia Capes, talked with Capt. Frank M. Bennet, USN, Commandant of the Mare Island Navy Yard,[13] with officers in the Department, and with his wife at their home in Washington.

During a telephone conversation with the Naval Radio Station, San Diego, instructions for the U.S.S. *Raleigh* then at Corinto, Nicaragua, were issued and relayed via radio in a total elapsed time of 4 minutes.[14]

Connections with various yards and stations were exceedingly rapid for the telephone system of that time.

Pensacola, 45 seconds	New York, 27 seconds
Great Lakes, 32 seconds	San Diego, 28 seconds

The undertaking was completely successful, and upon its completion Daniels sent his congratulations to Vail and to the Bell System which had gratuitously provided the services.

In reporting the results of the mobilization The Telephone Review, in its issue of June 1916, with justifiable pride, took some license in reporting the conversation of the Secretary to Captain Chandler as being the following:

> I will be in my office in the Navy Department at ten o'clock tomorrow morning. I will ring you up then and have another conversation. I can hear you as well as if you were in Washington, Captain Chandler. It will not be long before the Secetary of the Navy will be able to sit in his office and communicate with vessels of the Navy all over the world by wireless telephone. That is something the captains may not like! [15]

[13] Annual Report of the Secretary of the Navy, 1916, op. cit., pp. 146–147.

[14] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., G. H. Clark, "Radio in War and Peace," p. 250.

[15] The Telephone Review, op. cit., June 1916.

Hooper, who was present, in later years, when a rear admiral, gave another version of the Secretary's use of the radiotelephone and his conversation with Captain Chandler. The handset which contained both the microphone and receiver was identical with that now so common to the telephones in our homes, except it had a litle button that one pressed to talk and released to listen. The use of this button had been carefully explained to the Secretary. In the excitement of the moment, he not only pressed the button when he talked, but he continued to press it when endeavoring to listen. "Hello, hello, Captain Chandler," he said. Hooper, listening in on another phone, heard the Captain reply but not the Secretary. Again he shouted, "Hello, hello, I can't hear you. Speak louder!" The Captain dutifully obeyed, but he could not bridge the open circuit. Finally, realizing he was having no success and that he could not "spoil the show" with the newspapermen and cameramen about him, the Secretary, still grimly pressing the button, conducted an imaginary conversation with the captain. "I heard you fine. How is the weather at sea? That's fine. Glad you have such nice weather there. We have a fine day here, too." When others, perhaps less excited, took the microphone, two-way conversation was immediately established much to his never-admitted chagrin.[16]

Bullard strongly recommended that negotiations be entered into with the American Telephone and Telegraph Co., for permanent telephone and telegraph connections between the Navy Department and important yards and stations in time of peace. He closed his recommendation with the statement: "The desirability of such permanent circuits has been manifested on numerous occasions." [17]

[16] "Radioana," op. cit., Clark, "Radio in War and Peace," pp. 230–231.

[17] Letter, dated 31 May 1915, from W. H. G. Bullard to the Secretary of the Navy, files, Secretary of the Navy National Archives, Washington, D.C.

PERSONNEL

With the expansion of radio communications during 1915-16, personal shortages were acute. The Bureau of Navigation, charged with procuring and training personnel, managed to provide a sufficient number to man the fleet and shore stations. It was obvious that it would be extremely difficult to provide those with the necessary training should the country become embroiled in the war.

In December 1915 Bullard wrote the commercial operating companies letters suggesting that they should lay before their operators a letter from him suggesting they enroll themselves for Government service in the event of war. The companies, especially the Marconi Co., which was the only sizable one of that time, supported this idea wholeheartedly.[18]

At the same time, he wrote the National Amateur Wireless Association requesting the addresses of all persons who had enrolled in that organization.[19] The officers of the association responded to this request and offered all possible assistance. By March March 1916 the amateurs in the 1st Naval District were thoroughly organized. This was followed quickly by similar action in other districts.

The Annual Report of the Director of Naval Communications for 1916 stated:

> It is desired to make special mention of the commercial and amateur radio operators who have volunteered their services in time of public peril. Through the cooperation of commercial radio companies, 200 applicants have offered their services in time of war and additional applications are being received regularly. Similarly amateur radio organizations have cooperated with this office and the amateurs have been organized by districts throughout the United States, such organizations being under the immediate supervision of the district radio superintendent of the district concerned.[20]

[18] Multiple address letter, dated 14 Dec. 1915, from Director Naval Communications to various commercial radio companies, files, Naval Radio Service, National Archives, Washington, D.C.

[19] Letter, dated 15 Mar. 1916, from W. H. G. Bullard to National Amateur Wireless Association.

[20] Annual Report of the Secretary of the Navy, 1916, op. cit., p. 145.

FIGURE 19–1. Secretary of the Navy Josephus Daniels talking by radiotelephone from his office in the old State, War and Navy Department Building at Washington, D.C. with the USS *New Hampshire* off the Virginia Capes.

Following the successful organizations of the amateurs, the Bureau of Navigation, early in 1917, created the Class 4, United States Naval Reserve. This was the beginning of the Naval Communication Reserve which has been of untold assistance from that time until now, in war and peace, and during disasters resulting from earthquake, flood, or wind. The requirements for enrollment in this reserve group were American citizenship, ability to send and receive at the rate of 10 words per minute, and the passing of the usual physical examination. Upon enrollment, members received an annual retainer fee of $12 until they were able to pass qualifying examinations indicating their ability to replace regular naval radio operators. Upon qualifying, they received annual retainer pay equal to 2 months pay of their corresponding grade in the regular Navy. Additionally, they were paid travelling expenses to and from the place of training and the same pay as their corresponding grades while under training. Uniforms were provided gratuitously. During peacetime a member could be discharged at any time, upon his own request. Active duty was not compulsory, except in time of war.[21] The success in organizing this Communication Reserve Force was due to the enthusiastic support of the amateurs and their organizations.

REORGANIZATION OF NAVAL COMMUNICATIONS

By a precept, dated 6 December 1914, the Secretary of the Navy established a board to review the naval communications situation and to make recommendations to bring the Naval Radio Service up to a satisfactory state of war readiness. This Board was composed of Capt. W. H. G. Bullard, USN, Superintendent of the Naval Radio Service, the senior member; Commdr. S. W. Bryant, USN, Bullard's senior assistant; Lt. E. H. Dodd, USN, Pacific Coast Radio Superintendent; and Lt. S. C. Hooper, USN, who had just returned from the European war zone where he had served as an observer. Hooper also acted as the recorder. The initial report of the Board, dated 20 February 1915, recommended changes in responsibilities, organization, and administration of the system. Some of these changes were approved and instituted.

On 1 May 1916, the Secretary directed the Board to reconvene, review the situation, and submit a supplementary report.[22] The final recommendations of the Board were approved and implemented on 28 July 1916 by the promulgation of Navy General Order No. 226. This order established the Naval Communication Service, under a Director of Naval Communications, Office of the Chief of Naval Operations, and abolished the Naval Radio Service under the Chief of the Bureau of Navigation.

No written mission, as such, was assigned the Naval Communication Service, but it may be inferred from the duties of the Director as contained in the "Communication Regulations of the United States Navy," 1918 which states:

> The officer in charge of the Naval Communication Service is attached to the Office of the Chief of Naval Operations, and is known as Director Naval Communications. He is responsible for the efficient handling of all radio, telegraph, telephone, cable and signal work, including submarine signaling, and shall be in general charge of all dispatch work between the Navy Department and the fleet, and throughout the Naval Service outside the fleet. He will have charge of . . . Radio Censorship . . .[23] In the administration of all means of communication, he will have general charge of their operation, personnel, organization, administration, etc., and in fact everything which has to do with the Communication Service of the Navy, except material.

He shall be charged with:

> The preparation of communication regulations, all books for radio communication including . . .[24]

[21] The Wireless Age, May 1917, p. 596.

[22] Letter, dated 1 May 1916, (N–31/W 624–109) from the Secretary of the Navy to W. H. G. Bullard.

[23] The full sentence read "He will have charge of Cable and Radio Censorship, with the title of Chief Cable Censor." The responsibility for cable censorship was added on 28 April 1917.

[24] "Codes" have been deleted since they did not become a responsibility of the Director Naval Communications until October 1917.

calls,' and signals, commercial traffic regulations, etc., issue of detailed instructions for the operation stations in accordance with military efficiency, international agreements in force, and the laws affecting the operation of naval radio stations.

Control of the commercial work handled by naval radio stations, including issue of accounting and operating forms, auditing commercial accounts, traffic agreements, and accounting with commercial and other government managements involved.

He shall keep the Bureau of Steam Engineering advised of all matters within his cognizance requiring work of a technical nature, and annually on July 1 he will notify the Bureau of proposed changes in the general radio organization which would in any way affect the material.

He shall correspond directly with the naval service in accordance with the procedure laid down by the regulations in the case of bureaus and other offices under the Navy Department in regard to all matters in which he is authorized to take action. He shall correspond directly with private and commercial concerns upon matters of reciprocal interest relating the the commercial operation of naval radio stations in questions of interference, traffic arrangements, proposed change of rates, and accounting, and such matters as from time to time may be necessary in connection with the operation and efficiency of the Naval Communication Service.

He shall co-operate with officials designated by the Secretary of Commerce in reference to the location of proposed commercial stations, the licensing of operators, the control of the operation of commercial stations under the law, and the assignment of wave lengths for use by commercial stations which will comply with the law and prevent interference with the operation of the Naval Communication Service.

He shall co-operate with officers designated by the Secretary of War, when necessary, in all matters pertaining to naval communications of which he is in charge.

He shall submit to the Chief of Naval Operations, with his recommendation, a statement of all matters that require department action.

He shall submit such reports in regard to the naval communication establishment as may be called for by the Secretary of the Navy.

The necessary expenses of the office of Director Naval Communications will be borne by the Bureau of Steam Engineering.

He shall be charged with assignment to duty of all enlisted personnel of the communication service in accordance with instructions, issued by the Bureau of Navigation.

He shall be charged with the preparation and necessary revision of list of names of competent operators outside the Navy whose services can be obtained for the Navy by enlistment or employment in the event of the United States being engaged in hostilities. In order to obtain this list he is authorized to communicate, as may be necessary, with the officers of the Naval Reserve and Naval Militia organizations, commercial radio companies, and operators, and take such steps as may be necessary or advisable to arrange the lists mentioned above.[25]

Bullard and the personnel of the disestablished Radio Service were ordered to report to the Chief of Naval Operations, and the new service was established. Originally there were five assistants with the following titles:

Assistant Director Naval Communications with additional duty as Atlantic Coast Superintendent.
- Pacific Coast Superintendent.
- Philippines Communication Superintendent.
- Assistant for Commercial Traffic.
- Communication Officer, Navy Department.

Outside the Navy Department the Naval Communication Service was organized following the recently established naval district system. All stations in a district transmitted their traffic to the district center station which relayed it through the various district center stations to its ultimate destination. This organization was as follows:

ATLANTIC DIVISION

WASHINGTON, MAIN STATION:

1st District
- Boston, District Center
- Portland
- Portsmouth

2nd Division
- Newport, District Center
- Nantucket Lightship

3rd District
- New York, District Center
- Fire Island
- Fire Island Lightship

4th District
- Philadelphia, District Center

District of Columbia (independent)
- Washington
- Indian Head

5th District
- Norfolk, District Center
- Annapolis
- Diamond Shoals Lightship
- Beaufort

6th District
- Charleston, District Center
- Port Royal
- St. Augustine (arbitrarily placed)
- Frying Pan Shoals Lightship

[25] Communication Regulations of the United States Navy, 1918," (Press, Navy Recruiting Bureau, New York), article 201.

7th District
- Key West, District Center
- Jupiter

8th District
- New Orleans, District Center
- Pensacola
- Heald Bank Lightship
- Point Isabel

9th, 10th & 11th Districts
- Great Lakes, District Center

Guantanamo District
- Guantanamo, District Center
- Navassa Island
- Haitian Stations

San Juan District
- San Juan, District Center
- Porto Rican Stations
- Virgin Islands

15th District
- Balboa, District Center
- Colon

PACIFIC DIVISION

SAN FRANCISCO, MAIN STATION

12th Naval District
- (a) San Diego District
  - San Diego, District Center
  - Point Arguello
  - Farallons
- (b) San Francisco District (to Lat. 44° N.)
  - San Francisco, District Center
  - Eureka
  - Marshfield
  - Monterey

13th Naval District
- (a) Puget Sound District. (from Lat. 44° N. to Canada)
  - Puget Sound, District Center
  - North Head
  - Tatoosh
- (b) Cordova District (Alaskan Stations)
  - Cordova, District Center
  - Sitka
  - Kodiak
  - Pribilofs (St. Paul and St. George)
  - Dutch Harbor
  - Seward

14th District
- Pearl Harbor, District Center
- Tutuila (Samoa)

PHILIPPINE DIVISION

CAVITE, MAIN STATION (District Center)
- Olongapo
- Guam
- Peking (For delivery of ALNAV, etc., messages only; station administered locally.) [26]

[26] "Communications Regulations, U.S. Navy, 1918," op. cit., Article 105.

THE END OF NEUTRALITY

On the evening of 2 April 1917, President Wilson addressed the Senate and the House of Representatives, met in joint session, and asked that they declare that a state of war existed between the United States and the Imperial German Government. Immediately thereafter, resolutions to that effect had been introduced into both Houses. The Senate passed the resolution on 4 April. The debate in the House lasted through the following day and night and at 0300, 6 April the resolution was passed. The time set for delivery to the President for signature was shortly after 1300 of the same day.[27] At 1245, 6 April, the Radio, Virginia, station transmitted the signal directing all stations of the primary system of naval communications to "Cease all radio work and listen for rush signals." Every operator knew why and strained, listening for the historic message which would shatter the silence and which would embroil us in the largest scale conflict the world had known. Standing in a window of the Executive office, Comdr. Byron McCandless, USN, Acting Director of Naval Communications,[28] watched and, as the President completed his signature, signaled an assistant standing in a window of the old State, War and Navy Building, across the street from the White House grounds. With this signal the silence ended and in seconds the fleet, the shore stations, and most of the entire world, knew that we had entered the war on the side of the Allies.[29]

[27] David Saville Muzzey, "A History Of Our Country" (Ginn and Company, Boston 1943), pp. 665–666.

[28] Bullard had completed his tour of shore duty and had been ordered to sea. McCandless was Acting Director until Comr. D. W. Todd, USN, reported for duty as Director.

[29] The Wireless Age, June 1917, p. 614.

CHAPTER XX

Wartime Expansion of United States Naval Communication System

EXPANSION BY ABSORPTION OF COMMERCIAL FACILITIES

By Executive order, issued on the day war was declared, the Navy Department was directed to take over such radio stations within the jurisdiction of the United States as might be required by the Naval Communication System. The order further directed the closing of all such radio stations not necessary to the Government. In addition to the foreign-owned stations at Sayville, Long Island, and Tuckerton, N.J., 53 commercial stations became a part of the system on April 7. Most of these were the property of the Marconi Wireless Telegraph Co., of America. Twenty-eight of this number were unnecessary for wartime radio operations and were closed. Amateurs were directed to cease operations and to dismantle their transmitters. Most complied voluntarily once they became aware of the edict. Landlines were substituted for radio circuits wherever possible. Excluding Alaska, no commercial radio service was permitted except through stations operated by the military departments.[1]

Upon our entry into the war the following stations of the primary network of the naval shore radio system were operating or under construction:

U.S. Navy, for transpacific work:
- Cavite, Philippine Islands (near completion)
- Pearl Harbor, Hawaii (nearing completion)
- San Digeo, Calif.

U.S. Navy, for transatlantic work:
- Arlington, Va.

U.S. Navy, for other work:
- Darien, C.Z.

Federal Telegraph Co., for transpacific work:
- Lents, Oreg.
- South San Francisco, Calif.
- Heeia Point, Hawaii

Marconi Co., for transpacific work:
- Bolinas, Calif.
- Kahuku, Hawaii

Marconi Co., for transatlantic work:
- New Brunswick, N.J.

German-owned station for transatlantic work:
- Sayville, Long Island, N.Y.

Foreign owned, other than German:
- Tuckerton, N.J.

In order to relieve the congestion on the single transpacific cable, the Marconi circuit between California, Hawaii, and Japan, and the Federal Telegraph Co. circuit between California and Hawaii, were operated by the Navy primarily for handling commercial traffic.[2]

STATUS OF TRANSATLANTIC COMMUNICATIONS

Prior to the beginning of the war the commercial companies had not succeeded in establishing continuous and reliable transatlantic radio communication service. The Navy, by operating the augmented Tuckerton transmitting facilities and the existing facilities at Sayville, succeeded in increasing reliability, but there were long daylight periods during which communications

[1] Annual Report of the Secretary of the Navy, 1917 (Washington, Government Printing Office, 1917), p. 44.

[2] Ibid., p. 45.

could not be maintained. The American Marconi Co., spurred by competition, had completed a station at New Brunswick, N.J., which was initially fitted with a 350-kw. Marconi timed-spark transmitter that would have afforded service of about the same reliability as the other two stations. At the time of its completion its sister station at Carnarvon, Wales was taken over by the British authorities and it had remained without a running mate. Early in 1917 the General Electric Co. completed the first 50-kw. Alexanderson alternator. The Marconi interests were interested in this equipment but wartime considerations delayed final negotiations for its purchase. The General Electric Co., with the concurrence of the American Marconi Co., had commenced installation of this equipment in February for comparison with the Marconi transmitter. When the Navy took over the station this installation was practically completed. Under ideal conditions these two transmitters proved capable of handling some of the transatlantic traffic.[3]

The cables were, and continued to be, the primary means of communication between this country and her Allies, but they were overloaded, and reliable radio circuits became increasingly essential. In view of the increased importance of the cables it was considered that the Germans would endeavor to sever them as quickly as possible. However, they did not take such action until 4 June 1918, when they severed two of them at a location about 60 miles east of Sandy Hook, N.J.[4]

PLANS FOR AUGMENTING TRANSATLANTIC RADIO COMMUNICATIONS FACILITIES

Faced with an urgent need for the augmentation of communication facilities, the Navy Department made repeated recommendations that a high-powered radio transmitting station be constructed in France, and that a similar one be erected in the southern part of the United States, to provide continuous duplex radio communication between the two countries. On 29 October 1917, M. Tardieu, French High Commissioner to the United States, cabled his government:

> The American Navy considers as very important "the question to the construction of a new very powerful radio station. It requests to be informed without delay if it be decided to construct such a station. It promises all necessary assistance so far as concerns the rapid supply of American material which would be required."

Following this, Secretary Daniels, on 31 October, sent the following cable to the U.S. Naval Attaché, Paris:

> Request immediately full information relative to action being taken in France to establish new extra powerful radio telegraphic station. If material from the United States is necessary, inform us immediately.

The Inter-Allied Radio Commission, which had been formed to determine Allied communication requirements, had not decided upon the establishment of the transmitting station in France when, on 28 November 1917, General Pershing cabled the War Department urging that action be taken immediately to establish radio facilities capable of handling the traffic then being transmitted by cable. Immediately upon receipt of this cable a conference between communication officials of the Army and Navy was called to consider the problem. The conferees met in New London, Conn., on 4 December 1917, and again in Washington on 12 December. These two meetings were attended by representatives of the other Allied Powers.[5]

At the New London conference the Bureau of Steam Engineering proposed the following:

> The establishment of three receiving stations along the Atlantic coast of the United States connected to Washington by leased wires;

[3] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., G. H. Clark, "Radio in War and Peace," p. 263.

[4] Ibid., p. 285.

[5] S. C. Hooper, "The Lafayette Radio Station," Journal of American Society of Naval Engineers, vol. XXXIII, No. 3, August 1921, p. 401.

The enlargement of, and duplication of, equipment in existing high-power stations;

The erection of an additional station in the United States, so that a final plan of five transmitting stations might be fulfilled;

The provision of sleet-melting equipment for the various transmitting station antenna systems, in order to assure freedom from ice during the winter season.

The development in the allied countries, of the multiple sending and receiving station plan agreed upon for the United States; and

The further recommendation that a super-high-power station be erected abroad as an additional channel for trans-Atlantic communications.[6]

The conferees adopted this proposed plan and forwarded it, recommending approval, to the Inter-Allied Communications Committee which had been established in Paris. This committee approved the plan and requested that it be implemented. The U.S. Government approved the program and it became the basic plan for the improvement of the Naval Communication system.

IMPROVEMENT OF EXISTING TRANSMITTING FACILITIES IN THE UNITED STATES

The Alexanderson alternator, installed at New Brunswick, was the first of this new type of transmitter. Its auxiliaries included an entirely new method of reducing the energy-wasting antenna resistances; a new type of control; and a magnetic as well as an electronic amplifier. Antenna resistances were reduced by the use of tuning coils which were spread over the surface directly beneath the antenna, one end grounded and the other connected to the antenna area directly above it. This reduced the antenna resistance 75 percent and quintupled the radiation efficiency.

When the station was taken over, General Electric Co. officials requested that they be allowed to continue their experiments. Navy Department officials, seeking better means of transatlantic communications, readily acquiesced. By November 1917 sufficient information had been obtained to warrant discontinuance of tests to make improvements to the equipment. When these were completed, the operation of the 50-kw. alternator was superior to the Arlington 100-kw. arc and the New Brunswick 350-kw. timed spark.

Seeking to further improve transatlantic communications, the Bureau of Steam Engineering, on 1 October 1917, addressed a letter to the General Electric Co. asking if they had one or more larger alternators. The reply stated that one 200-kw. alternator, complete with accessories, would be ready for testing in January 1918. The American Marconi Co. was asked to have it installed at New Brunswick, but their officials refused to defray the costs. Following receipt of this information the General Electric Co. agreed to install it at their expense. Work on the foundations commenced immediately, and the final installation was completed by June 1918. While the transmitter was being installed, improvements were made to the antenna supports and to the antenna and ground systems. Upon completion, 400 amperes could be delivered to the antenna. From July 1918 through February 1920 this station carried the bulk of the radio traffic between this country and Europe. It was the first high-powered station on the Atlantic coast that transmitted radio messages continuously and reliably.[7] It was later utilized for radiotelephonic communication with the U.S.S. *George Washington* during President Wilson's trips to and from France during the peace conference.

Much of the success of this station was due to the patriotic efforts, the unselfish expenditure of funds and the hearty cooperation of the officials of the General Electric Co. Dr. Alexanderson later stated:

The two years following the taking over of the New Brunswick station by the Navy formed a particular-

[6] "History of the Bureau of Engineering, Navy Department, During the World War" (Washington, Government Printing Office, 1922), p. 93.

[7] "Report of the Federal Trade Commission on the Radio Industry" (Washington, Government Printing Office, 1924), p. 15.

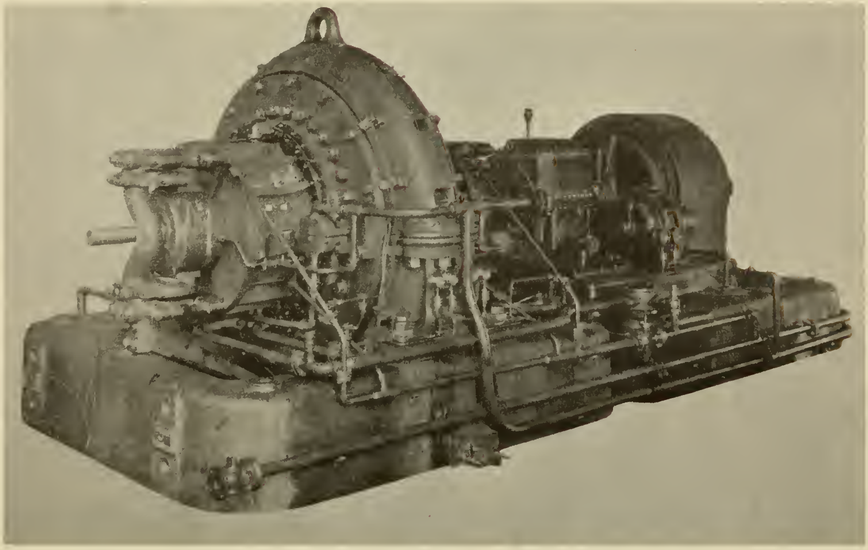

FIGURE 20–1. Two hundred KW Alexanderson alternator, New Brunswick, N.J., 1918.

ly productive period, and one on which I look back upon with great satisfaction and pleasure. A real friendship developed between the G. E. personnel and the Navy personnel. A spirit of effective cooperation was developed which one does not find very often. In spite of the fact that our early installation was very primitive, or what is known as 'hay-wire', the Navy helped us wholeheartedly to arrange for reception tests with distant points.[8]

During 1917 the Sayville station was used for transatlantic work when conditions permitted. In consonance with the New London recommendations, work on the installation of a 200-kw. arc transmitter and other improvements were begun in the early part of 1918. This transmitter was also ready for operation by July 1918. It afforded increased reliability of transatlantic transmissions but did not possess the capabilities of the New Brunswick alternator.

A 100-kw. arc transmitter with additional power-generating equipment was installed at Tuckerton. During the period improvements were being made at New Brunswick and Sayville, it handled most of transatlantic transmissions. After the installation of the 200-kw.-arc alternator at New Brunswick was completed, Tuckerton was used primarily for fleet broadcast purposes.

No endeavor was made to increase the size of the transmitter at Arlington as that station had sufficient power for the fleet broadcast purposes for which it was utilized.

THE ANNAPOLIS TRANSMITTER STATION

Pursuant to the decision of the Inter-Allied Radio Committee, a site for an additional high-powered radio station on the Atlantic coast was selected at Annapolis, Md., across the Severn River from the Naval Academy. Construction commenced immediately under the supervision of Lt. Comdr. George C. Sweet, USN. The antenna, a four-sided, flattop, each side 400 feet long and supported by four 500-foot towers, was designed by Mr. L. F. Fuller, of the Federal Telegraph Co. The towers were spaced as far apart as possible, the limiting factor being the tensile strength of the antenna wires. With the maximum spacing, giving maximum possible antenna capacity, corona discharges were expected unless steps were taken to eliminate them. The Federal Telegraph Co. designed aluminum corona shields at their Palo Alto laboratory and, in conjunction with the Ohio Insulator Co., designed insulators of high tensile strength and low electrostatic capacity. These refinements permitted the use of 500-kw. transmitters in lieu of the originally planned 350-kw. ones. The transmitting equipment, which was in duplicate, was installed under the supervision of Mr. Haraden Pratt, then an expert radio aid. The station was placed in service in September 1918 and was satisfactory for transatlantic communications, but was not as capable as the New Brunswick station, equipped with the 200-kw. alternator.[9]

THE LAFAYETTE TRANSMITTER STATION

Following the approval of the New London recommendations by the Inter-Allied Communications Commission, Lt. Comdr. E. H. Loftin, USN, was ordered to Paris, where he was immediately made a member of the Inter-Allied Radio Committee and of the Inter-Allied Technical Radio Committee. At one of the first meetings he attended he outlined a proposal for construction of the station in France and convinced General Ferrie, of the French Communication Service, that the U.S. Navy had the experience and facilities for the construction of this proposed most powerful radio station in the world.[10]

Owing to wartime conditions in France,

[8] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 264.

[9] Ibid., pp. 282–284.

[10] Ibid., p. 290.

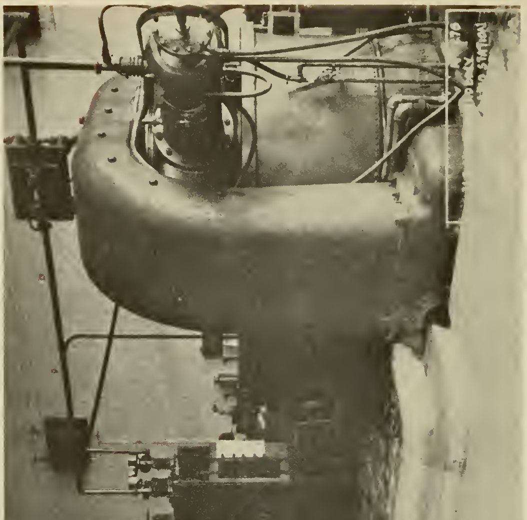

FIGURE 20-2. Dual installation 500 KW Poulsen arc transmitter, Annapolis, Md., 1918.

the particular skills required for the erection of the towers to support the antenna system were virtually nonexistent. It was agreed that the station would be constructed jointly by the two countries. The French would provide the site, construct the buildings and the foundations for the towers. The United States would provide and erect the towers and antenna system and would furnish and install two completely duplicate 1,000-kw.-arc transmitters with accessories. It was agreed between the U.S. War and Navy Departments that the latter would assume full responsibility for the construction of this country's portion of the station.[11]

The Bureau of Yards and Docks immediately worked out the design of the towers and placed them under contract with the Pittsburgh-Des Moines Co., of Pittsburgh, Pa. Meanwhile, the Bureau of Steam Engineering completed installation plans for the arc transmitters, which were placed under contract with the Federal Telegraph Co. L. F. Fuller, chief engineer of that company, designed the ground and antenna system. The antenna system support consisted of eight 820-foot towers, 1,312 feet 4 inches apart, on centers, erected in a quadrangle 1,312 feet 4 inches by 3,937 feet on centers. The only structure in the world which was higher at that time was the Eiffel Tower.[12]

The Annapolis station, which was being rushed to completion, placed a heavy drain on qualified labor available to the Navy. Notwithstanding this, a force in excess of 600 riggers, steelworkers, bridgemen, electricians, and other skills was quickly assembled. The first unit of these arrived in Bordeaux in the early spring of 1918. Construction of that part of the station for which the United States was responsible commenced on 28 May 1918 at the site selected near the village of Croix d'Hins, about 14 miles southwest of Bordeaux.

Shortage of shipping facilities for such large quantities of fabricated steel slowed delivery, but by 1 October 1918 practically all the tower material and the radio transmitters had arrived. The construction was proceeding rapidly when the cessation of hostilities, on 11 November 1918, nullified the urgent military requirement for the station. Work was stopped in early December when it became apparent that hostilities would not be renewed. The construction force was returned to the United States and only a small caretaking group was left at the station pending final disposition of the project.

After considerable deliberation, the French Government expressed the desire to have the station completed by the United States. A new formal agreement between the two Governments was drawn up and approved. In this, the U.S. Navy was to complete the station and the French Government was to assume the costs of all labor, material, and equipment.[13] The Navy contracted the Pittsburgh-Des Moines Co., fabricators of the towers, to complete the erection. This work was recommenced on 4 May 1919 and completed in January 1920. The remaining work on the antenna system and the installation and testing of the transmitters was continued, utilizing naval uniformed personnel and civilian radio engineers employed for duty at the station.[14]

Operational tests were satisfactorily completed on 20 September 1920. Immediately thereafter the French operators were given training. On 15 November the station was turned over to them for operation and on 18 December it was formally turned over to the French Government and American personnel were withdrawn. The cost of the station was $3,500,000. On this date the following radio message was transmitted by Annapolis.

[11] Hooper, op. cit., p. 404.

[12] D. Graham Copeland, "Steel Tower Construction at The World's Greatest Radio Station," U.S. Naval Institute Proceedings, Annapolis, 1920, p. 290–291.

[13] Annual Report of the Secretary of the Navy, 1920 (Washington, Government Printing Office, 1920), p. 57.

[14] Copeland, op. cit., p. 292.

Washington, D.C., Dec. 18, 1920

Minister of Marine, Minister of War and
Minister of Posts and Telegraphs,
Care United States Naval Attache,
Lafayette Radio Station.

Cordial felicitations are extended to the Republic of France through the medium of the Annapolis Radio Station on the occasion of the inauguration of the Lafayette Super High High-Power Radio Station. It is our firm conviction that as a result of the mutual co-operation and endeavors of the representatives of the French and American peoples engaged in the work incidental to the establishment of the great Lafayette Radio Station a notable advance has been made in the scientific progress of the world which will result in enduring benefit to France and to all mankind.

Josephus Daniels,
Secretary of the Navy [15]

Shortly after this was transmitted the following was received at the Navy Department:

Lafayette Radio Station, France
December 18, 1920

To the Secretary of the American Navy,
Washington, D. C.

I desire that the first message sent after the official inauguration of the Lafayette Radio Station be a cordial greeting to the Republic of the United States of America. In the name of the French Government I send many thanks to the American Navy for the great part which it played in the construction of the most powerful radio station in the world. This collaboration maintained during the period of peace strengthens still further the unalterable friendship born of common struggles and victories.

Deschamps,
Asst. Secretary of Posts and Telegraphs.[16]

A bronze commemorative plaque embodying the seals of the United States and France was placed over the main entrance to the operating building and was unveiled by M. Deschamps, Assistant Secretary of Post and Telegraphs. It contains the following inscription in both French and English.

LAFAYETTE RADIO STATION

IN HONOR OF GENERAL LAFAYETTE

Conceived for the purpose of insuring adequate and uninterrupted transatlantic communication facilities between the American Expeditionary Forces engaged in the World War and the Government of the United States of America.

Erected by the United States Navy in conjunction with and for the Government of France.

Work Started 28 May, 1918

Completed 21 August, 1920[17]

During the construction period considerable friction arose between the French and American officials concerning the antenna and ground systems. Based upon his experience with naval high-powered arc installations, Fuller had made detailed drawings of these systems. These were flatly refused by the French, who later assumed responsibility for the design of the ground system. The antenna design, with minor changes, was finally used but the plans were redrawn, copied line for line except the words "Federal Telegraph Company" were eliminated and in lieu thereof were substituted, "designed by Captain Brassier." Thus was national pride assuaged. The French also resented the use of arcs instead of alternators because the arc harmonics would create radio interference over all of France.[18] As early as July 1920 they were planning the installation of a 500-kw. alternator of their own design and this was later installed.[19]

The remarkable work of the Federal Telegraph Co. in furnishing the transmitting equipment in record time was extolled by the Chief of the Bureau of Engineering in a letter to the company, dated 15 October 1920, which stated:

The Bureau desires to congratulate your company in connection with the excellent results obtained with the duplicate 1000 KW arc equipment which was purchased from the Federal Telegraph Company and installed at the Lafayette Radio Station at Croix d' Hins, France.

The results of the thirty day tests of this equipment are very satisfactory to the Bureau, the comparative strength of Lafayette's signals being three to five times as great as those from other European high-power stations, and solid copy being constantly obtained not less than 22 hours out of the 24, notwithstanding the fact that the tests were conducted during the most unfavorable static season.

The services of your Chief Engineer, Mr. R. R.

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[15] Hooper, op. cit., p. 407.

[16] Ibid.

[17] Ibid.

[18] "Radioana," op. cit., Clark, "Radio in War and Peace," pp. 291–293.

[19] Radio Electricite, July 1920.

Beal, as the Bureau's representative to conduct the tests, under the authority of the commanding officer of the Lafayette Radio Station, were most praiseworthy and satisfactory, the entire tests having been conducted under Mr. Beal's supervision without interruption or casualities to the equipment.

The Bureau feels that the results obtained at the Lafayette Radio Station reflect great credit on the Federal Telegraph Company as well as the Navy.

Credit for performance of duty above that expected is due all the personnel who, during the wartime construction period, worked during all the daylight hours except during the midsummer months when the heat was so excessive that it was necessary to stop during the middle of the day. The wartime work at the site was under the administration of Lt. Comdr. George C. Sweet and the tower construction was under the supervision of Comdr. F. H. Cooke (CEC), USN. The postwar construction was performed under the direction of Capt. A. St. Clair Smith, USN, Naval Attaché, Paris. Lt. Comdr. D. Graham Copeland (CEC), USN, was his construction supervisor.[20]

PLANNING THE ADDITIONAL US HIGH-POWERED STATION

The severe winter of 1917–18 demonstrated the damaging effect of sleet upon antenna systems. Sleet-melting systems, whereby 60-cycle current could be fed to the antenna system at low voltage and high amperage, to heat them above the sleet-melting point, were installed at all major stations. The use of this device necessitated an undesirable stoppage of transmission.[21] It was desired to locate a new high-powered station inland, beyond the range of bombardment by ships or from attack by the shipborne aircraft of the time, in an area which had been free of sleet for the preceding 10 years and yet within reasonable proximity of Washington. Some location in North or South Carolina[22] was deemed to satisfy these requirements. In July 1918, Pratt and Clark were directed to locate a site in North Carolina with satisfactory power supply, good ground conditions, and nearby recreation facilities. During the 2 weeks of the survey heavy rains fell throughout the area and after driving through many miles of slippery, muddy roads they selected a site at Monroe.[23] Pratt later stated "only our Federal badges enabled us to get transportation at times, also to escape village constables and revenue agents."[24]

The plans for this station were unique. The acute steel shortages which existed in the latter days of the war necessitated the substitution of 20 brick chimney structures, 500 feet high, in lieu of four self-supporting towers. The top portions were to be of porcelain brick which would serve as insulators, thereby increasing the effective height of the antenna by eliminating the capacity that would exist between the antenna wires and the lower portions of steel towers.[25] The bottoms of the structures were to be of such diameters as would allow them to be used as buildings for housing the powerplants and transmitters.[26] Federal arc, 2,000-kw., transmitters, which were to be installed in duplicate, would make it the world's most powerful station.[27]

By the date of the armistice, the contract for the transmitters had been made and the future output of many of the brickyards in the South had been placed under contract. Cessation of hostilities brought the project to a stop and, to the regret of radio engineers throughout the world, it was finally abandoned. The idea of using the chimney-

[20] Copeland, op. cit., p. 293.

[21] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 286.

[22] Secretary of the Navy Josephus Daniels was a native of North Carolina.

[23] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 286.

[24] Undated memorandum Haraden H. Pratt to George H. Clark.

[25] A later naval adaptation of this idea was the use of opposing mountain ridges as supports for high-powered, low-frequency antenna systems.

[26] "Radioana," op. cit., Clark, "Radio in War and Peace," pp. 287–288.

[27] "History of the Bureau of Engineering, Navy Department, During the World War," op. cit., p. 96.

type structures to reduce power losses and to house equipment had appealed to everyone.[28]

EFFECT OF THE WAR ON RADIO TRANSMISSION FACILITIES

The catalytic effect of war brought about a rapid development of higher powered radio transmitters. Prior to 1917, 350-kw. power was considered the achievable upper limit. The Annapolis station represented a material increase, and the Lafayette station was of theretofore undreamed-of power. Despite this the Federal Co., with the experience gained in building more powerful equipment, was willing to accept a contract for equipment twice as powerful as any yet constructed. The 200-kw. Alexanderson alternator, the most efficient high-powered transmitter yet built, though conceived prior to our entrance into the war, was rushed to completion by the urgings of the Navy Department.[29]

EXPERIMENTATION WITH DIRECTIVE AND BALANCED RECEIVING ANTENNA SYSTEMS

Prior to the entrance of the United States into the war there were no separate and remote facilities for the reception of transatlantic signals. Some progress had, however, been made in duplexing other high-powered stations so that transmission and reception might be accomplished simultaneously.

At this time two series of receiving antenna system experiments were being conducted: one, the use of an underground system; and the other, a means for increasing the signal-to-noise ratio. These two series of experiements soon merged.

Just north of Washington lived an elderly gentleman, Dr. J. H. Rogers, who had become interested in radio reception utilizing underground antenna. At his Hyattsville, Md., laboratory he had constructed a maze of various types of antenna extending in all directions from an underground receiving hut. There were bare wires, insulated wires, wires in lead conduit, wires in sewer pipe, all buried in the earth. Some were of short, some were of medium, and some were of long length. Reception was normally accomplished by connecting the receiver to two wires stretching out in opposite directions. Rogers was so insistent that he had discovered a cure for static that the Bureau sent representatives to inspect his method. Clark witnessed tests of it on 16 December 1916. He reported that the antenna could not be sharply tuned because of the great distributed capacity, and that in receiving arc-transmitted signals more trouble was encountered with harmonics than when a sharply tuned elevated antenna was used. However, he recommended further investigation of the promising indication that the system would give a better signal-to-noise ratio because of its static-reducing and directive properties.[30]

Dr. Hoyt Taylor,[31] USNR, was, at this

[28] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 288.

[29] "History of the Bureau of Engineering Navy Department During the World War," op. cit., p. 95.

[30] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 348. A description of the Rogers collector system is contained in app. M.

[31] Taylor was born in Chicago, Ill. He entered Northwestern University in 1896. In 1899 he entered the employ of the Western Electric Co. Returning to Northwestern in 1900, he lacked but one semester of graduating when lack of funds forced him to accept a position as an instructor at Michigan State College. In 1902 he was awarded his bachelor of science degree by Northwestern University. Following this he became an instructor at the University of Wisconsin. In 1908 he was granted a year's leave of absence which he utilized to take postgraduate work at the University of Goettingen, Germany, where he obtained his doctorate. Returning to America, he accepted the position as head of the Physics Department, University of North Dakota. He continued in this capacity until 1917. Meanwhile, he had become a Naval Reserve officer and upon the outbreak of the was was assigned duty as District Communications Officer, Ninth Naval District, Goat Lake, Ill. From this time he continued his association with the Navy until his retirement in 1950.

time, the District Communication Officer of the 9th Naval District with headquarters at Great Lakes, Ill. Early in 1917 he was directed to establish a temporary laboratory on the shores of Lake Michigan and to conduct investigations, using buried and submerged antennas, to determine their directional and static-reducing properties. From the results of his investigations it was decided that the method possessed possibilities in the reduction of static. Low-frequency arc signals emanating from a distance could be heard well, but the reception of signals from spark transmitters was poor. Local electrical storms affected reception much less than they did with an elevated antenna. It was discovered that the underground collector was aperiodic and that several stations transmitting on different frequencies could be received on the same one. Following further tests, Taylor discovered that wires submerged in fresh water gave signal strengths 10 times stronger than the same type laid underground. Other tests indicated an optimum length of wire for a given frequency, and that the best was one-eighth of the wave length.[32] In In October 1917 it became necessary to transfer Taylor to other duty and, although the experiments were continued, they resulted in no further gain of information.

There appeared to be valuable features in the undersurface collector system. In an endeavor to hasten and extend the range of the experiments, Lt. E. H. Loftin, USN, who had completed his duty in Paris and had been ordered as District Communication Officer of the 10th Naval District with headquarters at New Orleans, was directed to conduct experiments to determine the feasibility of utilizing such a system operationally. Extensive trials were conducted over a 3-month period during which time it was learned that the directive feature of this type of collector eliminated much of the interference created by the proximity of transmitters to receivers. Underground receiving antenna systems were installed at Norfolk, New Orleans, and Great Lakes, all important relay stations. These systems permitted simultaueous transmission and reception and approximately doubled the traffic capabilities of those stations. The same increase could have been accomplished by distant separation of the transmitter and receiver stations, but at far greater effort and cost.[33]

With the knowledge obtained from these experiments, Dr. Austin conducted scientific studies endeavoring to obtain exact reasons for the results which had been obtained. He reached the conclusion that the reduction in static was due to the balancing property inherent in the types of subsurface collectors used and that directivity was inherent when the direction of the antenna and the bearing of the transmitter were the same. During the summer of 1918 he developed several balanced circuits, one of which, utilizing the aperiodic quality of a subsurface collector, was used for multiple reception of signals at various receiving stations.[34]

Prior to the taking over of the transatlantic stations by the Navy, the Marconi Co. had been conducting static-elimination experiments at Belmar in an endeavor to increase the number of hours in which traffic could be successfully received from European sources. These experiments were based on the premise that unwanted signals might be balanced out by properly designed antenna systems. Dr. Roy A. Weagant, Chief Engineer of the American Marconi Co., was the director of these experiments. Upon assumption of control of the station, the Navy not only concurred in the continua-

[32] "History of the Bureau of Steam Engineering, Navy Department, During the World War," op. cit., pp. 101–102; A Hoyt Taylor, "Radio Reminiscences: A Half Century" (Naval Research Laboratory report), pp. 79–82. A description of the Taylor collector system is contained in app. M.

[33] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 350.

[34] "History of the Bureau of Engineering, Navy Department, During the World War," op. cit., pp. 103, 107.

tion of Weagant's work but in the following months supplied him with all the information derived from its own experiments.[35]

Weagant's method was based on the use of two opposing, tuned, single-loop antennas supported on towers 400 feet high and connected through a three-winding transformer. In an early test, on a day when static was deafening, he succeeded in reducing this to a mere background murmur while signals from the station at Lyons, France, on a frequency of 22.2 k., came in loud and clear. However, the height of the towers required to support the loops militated against their usage. The Navy suggested the use of multiturn smaller loops and, following this suggestion, the Marconi Co. erected 10-turn loops 75 feet long and 40 feet high. In comparative tests these loops proved much more effective.[36]

In October 1917 the Navy activated the Belmar station as a transatlantic receiving station. Taylor, who was more inclined toward the use of the underground system than the Weagant balanced system, was ordered in command. Weagant's experiments and Taylor's emplacement of his underground wires mutually interfered. The Marconi Co. moved their experiments to Miami, Fla., where severe static is experienced the year round. The Navy detailed Clark to represent it in further Marconi tests. At Miami the Weagant system was markedly superior to the best subsurface wire system which could be installed.[37]

The Weagant system was also superior to any of the collector systems devised during this period. Taylor, who possessed an abiding faith in the subsurface system and in its future development, failed to appreciate that the balanced-loop system allowed the reception of signals which could not be copied using a subsurface system. The Proctor system, later installed at the Navy's Otter Cliffs, Maine, receiving station, did have static-reducing qualities and was simpler to install and easier to operate.[38]

Weagant and Taylor both filed patent claims on their collector systems. These actions precipitated interference claims between Weagant and Taylor and with Mr. John V. L. Hogan, who had also worked on similar ideas. The issue was finally settled by compromise, with the patent being issued to Taylor, who sold it to the Radio Corp. of America, which, in turn, for a nominal amount licensed the Navy to manufacture and use it and the Alexanderson barrage system.[39]

AUGMENTATION OF RECEIVING FACILITIES

The stations at Tuckerton and Sayville were used for transatlantic reception until October 1917. At Tuckerton the receiving antenna was a single wire, 4 miles long, supported by telephone poles. This antenna was almost aperiodic and had some directional qualities due to its azimuth. The transmitting antenna was not used directly for reception but was grounded when receiving so that it reradiated upon the receiving antenna, increasing the strength of the signals. At Sayville the counterpoise was divided into halves, with the northeast half connected to one binding post of the primary circuit and the southwest half to the other, without use of a ground connection. The primary circuit was coupled to the secondary which was connected to a two stage radio-frequency amplifier, which in turn, was connected to the detector circuit and thence to a two-stage audiofrequency amplifier. Frequency changing was complicated and difficult. Due to the directive property of the counterpoise the signal strength was fairly good. This station

[35] Ibid., p. 105; "Radioana," op. cit., Clark, "Radio in War and Peace," p. 353.

[36] Ibid., pp. 351–353. A description of the Weagant collector system is contained in app. M.

[37] Ibid., pp. 354–358.

[38] Ibid., pp. 264–267.

[39] Taylor, op. cit., p. 99.

was the primary transatlantic receiving station during the winter of 1917–18.

The Tuckerton and Sayville stations were connected with the Radio Central at the Navy Department by leased landlines. The transatlantic receiving was done at these stations and manually relayed to Washington. Outgoing transatlantic messages were delivered to the stations by landlines and the transmitters were keyed locally.

Receiving conditions on the transatlantic circuits were poor during the summer of 1917. In an endeavor to improve them it was decided to duplex the circuits by utilizing the Marconi station at Belmar, N.J., for reception. This station, built in 1914, as a receiving station for the Marconi transmitting station at Carnarvon, Wales, had not been utilized by the Marconi Co., except for experimental purposes. The operating building was located on the edge of a shallow inlet of the Shark River. Taylor installed an intricate system of submerged and underground collectors, laid out with the operating building as a center and on a line of bearing with Europe. This work was completed by October 1917 and the station was placed in operation. The transmitting stations at Tuckerton and Sayville were connected by landlines and the transmitters were keyed from Belmar.[40] Reception was improved but solid copy was unattainable, necessitating the continued assistance of Sayville for receiving.

In November 1917, the Marconi station at Chatham, Mass., was established as a receiving station to assist Belmar. Submerged and underground collector systems were installed. Reception at this station was of no aid because Belmar could invariably make solid copy of all signals which it could copy. During the operations there, it was learned that collectors submerged in salt water gave weaker but more static-free and receivable signals than those submerged in fresh water or buried in the earth.[41]

[40] "History of the Bureau of Engineering, Navy Department, During the World War," op. cit., p. 105.

[41] Ibid.

Despite Taylor's endeavors at Belmar and Chatham, the reception of oversea transmissions was not possible at all times. Early in the war a young and talented amateur, Alessandro Fabbri, who owned an elaborate amateur station at Otter Cliffs, Bar Harbor, Maine, turned this station over to the Navy for research purposes. Fabbri had, in turn, been commissioned an ensign in the Naval Reserve Force and ordered in command of the station. He was directed to copy the European stations and his success in continuous reception caused Taylor to shift his experimentation from Belmar to Bar Harbor. The rugged terrain and the rocky coastline around the Bar Harbor station did not lend itself to the succesful use of subsurface collectors. Hence, "blind end" loops were installed by the Wireless Specialty Apparatus Co.[42] A number of these small loops housed in huts of telephone-booth size were installed all over the Fabbri estate. Although this system was inferior to Weagant's, it worked well at Bar Harbor because the direction of the source of static was normal to that from which the signals emanated.

By midsummer of 1918, receiving conditions at Bar Harbor were satisfactory on all frequencies used on the transatlantic circuits. It then became the primary receiving station for this purpose. The received signals were "patched through" and carried over leased wires to Radio Central, Washington, where they were copied. The keying controls for all transatlantic transmitters were also transferred to Washington at this time.[43] The Chatham and Belmar stations were disestablished in October 1918 and February 1919, respectively.[44]

[42] This design of this collector system had been attributed to many people, Pickard, Fabbri, Wood, and Proctor. The latter was at the time chief engineer of the Wireless Specialty Apparatus Co. and the system was patented in his name. In a letter dated 25 Jan. 1920, Fabbri supported Proctor's claim. A description of the Proctor collector system is contained in app. M.

[43] Taylor, op. cit., p. 101.

[44] "History of the Bureau of Engineering, Navy Department, During World I," op. cit., 105, 107.

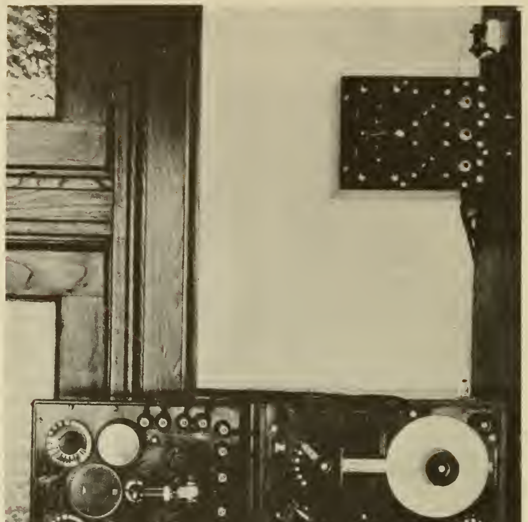

FIGURE 20–3. Standard Navy receiver, audion and amplifier, Radio Station, Belmar, N.J.

PURCHASE OF COMMERCIAL SHORE STATIONS

The U.S. Government's appropriation of the commercial shore stations necessitated paying rightful compensations to their owners. When the income of a station could be determined, payment was made on the basis of revenue and property value. A fixed rental was agreed upon for the low-powered stations which were continued in operation, with lower rates being paid for those which were closed. The Navy maintained all the stations that were kept operative, while their owners paid taxes and insurance.[45]

Early in 1918 the U.S. Shipping Board requested the Navy to make arrangements for the purchase of all radio stations on vessels owned or operated by them. The Marconi Co. was unwilling to sell these installations unless the coastal stations were included. The Navy acquiesced to this and, on 1 November, purchased, at a cost of $798,500, the low-powered stations which had been taken over from the Marconi Co., plus the high-powered stations at Ketchikan and Juneau, Alaska, and Astoria, Wash., and the obsolete station at South Wellfleet, Mass.[46]

Except for those mentioned, this transaction did not include any of the operating high-power stations used by the Marconi Co., for long-distance radio communications during peacetime. The parent company, British Marconi, intended to resume such operations as soon as possible, and was making plans to utilize continuous-wave equipment. They had already negotiated for the exclusive use of the Alexanderson alternators, but this was being held in abeyance. It became known that they were also interested in the purchase of the patents and stations of the Federal Telegraph Co. The acquisition of these patents would give them control over the American rights to Poulsen arc patents, and the arc transmitters would complement the alternator since it could be utilized for their low-power requirements. To avoid complications and to obtain control of the Federal patents, the Navy, on 15 May 1918, acquired these together with three high-power and five coastal stations for $1,600,000.[47]

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[45] "History of the Bureau of Engineering, Navy Department, During World War," op. cit., p. 113.

[46] Ibid., pp. 113–114.

[47] Ibid., p. 113.

FIGURE 20–3. Standard Navy receiver, audion and amplifier, Radio Station, Belmar, N.J.

CHAPTER XXI

Improvement of Radio Equipment During World War I

TRANSMITTERS [1]

There was little wartime improvement of damped-wave radio transmitters. This was due to the early realization by our naval radio engineers of the superiority of continuous wave transmissions. During the war the Navy purchased additional spark transmitters only because of insufficient manufacturing facilities for the production of undamped equipment of lower powers, and for fitting aircraft.

The war stimulated the development of three types of transmitters: The arc, the alternator, and the lower-power vacuum tube. The higher powers required for long-distance communication necessitated continued efforts to increase the power of both the arc and the alternator. Requirements for lightweight voice transceivers for the submarine chaser and aircraft programs spurred the development of electronic equipment and resulted in the later development of vacuum tube transmitters of all sizes.

The arc transmitter was progressively increased in power from the 30-kw. that had been installed in Arlington, to 100kw. for Darien, to the 200 kw. for Chollas Heights, to 350kw. for Pearl Harbor and Cavite, to 500kw. for Annapolis and, finally to 1000 kw. for Lafayette. Plans called for 2,000kw. at the never-to-be-built Monroe station. The Federal Telegraph Co. had wailed, protested, and almost refused to construct the 100-kw. arc for Darien. The Navy would not compromise, firmly believing that the power of this type of transmitter could be increased manyfold. Opposition decreased as success was obtained in constructing the higher and still higher powered equipments. By the time the contract for the Lafayette transmitter was made, Mr. L. W. Fuller, Chief Engineer of the Federal Co., believed he could successfully design an arc of 5,000kw.[2]

In explanation of this optimism, he said that at the time he went with the Federal Co., in 1912, they had succeeded in building a 30kw. which would deliver a proportionate amount of power to the antenna as compared with the lower-power ones. When the power input was increased beyond this, it had all gone into the production of heat. The higher powers were obtained by increasing the size of the magnetic field between the two electrodes to permit it to deionize the arc gap every radiofrequency cycle. This was accomplished by constructing a small size model of the magnetic circuit for each arc power rating. It was found that the flux density checked with that predicted by the model. Therefore, it was only necessary to provide an adequate magnetic field by proper increase of the sizes of the electrodes and the volume of the arc chamber.[3]

However, the arc was inferior to the alternator as a transmitter. At that time it utilized two frequencies for normal operation, a transmitting one and a compensating one, it emitted many harmonics, and had a slight

[1] Descriptions of these transmitters are contained in appendix M.

[2] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., G. H. Clark, "Radio in War and Peace," p. 300.

[3] Ibid., pp. 304–305.

frequency variation that made it somewhat the equivalent of a broad-wave transmitter.[4] The alternator had no harmonics and transmitted but one sharply defined frequency. Arcs could be built in sizes adapted to shipboard installation, but this was not feasible with the alternator. The higher power of the second alternator installation at New Brunswick and the improvements made by Alexanderson in that installation made it the most sought after transmitting equipment of the time for long-distance point-to-point circuits. These two types of transmitters, each used for the purposes best adapted, would have remained supreme for years except for one thing, the controllable oscillating properties of the three-element vacuum tube.

VOICE MODULATED TRANSCEIVERS

Consideration had been given to the construction of submarine chasers sometime before our entry into the war. The design was completed and contracts for hull and engine construction were entered into on 2 April 1917. It was planned to construct over 300 of these seagoing boats and to equip them with the latest devices available to enable them to be used in submarine hunter-killer groups. Their tonnage restricted the size of the crew and necessitated the utilization of as much automatic equipment as possible. Visualizing the need of radio telephonic equipment for this "mosquito fleet," the Bureau of Steam Engineering, in March 1917, contracted with the Western Electric Co., for 15 radiotelephone transceivers for experimental purposes. This equipment, assigned the Bureau designation, CW 936, was well known to all naval communication personnel during the war and the "twenties." [5]

This first completely successful voice modulated equipment was designed for use on any one of five frequencies. The frequency could be shifted to any one of these, all of which were within the band 500–1,500 kc, by means of a simple frequency change switch which cut in different fixed values of capacity and inductance for each of the five switch positions. This equipment quickly came into demand by all types of ships in both our own and the Royal Navy. Over 2,000 of them were purchased and installed on combatant vessels. More important, it was the predecessor of the modern vacuum tube transmitter and provided our personnel with the operational knowledge that would later cause them to demand tube transmitters of higher and higher powers, covering broader portions of the frequency spectrum. It was the herald of broadcasting, television, and reliable and economical long- and short-distance radiotelephony. Greatly improved voice and telegraphic equipments would be developed in the coming years but, as late as 1930, the fleet was placing great dependence upon the CW 936, by that time modified for radiotelegraphic transmission and used for tactical purposes.[6]

RECEIVING EQUIPMENT [7]

With the advent of the vacuum tube as a detector, amplifier, and radiofrequency driver (heterodyne), it was normal practice to house separately the primary and secondary circuits (commonly called the receiver), the detector, the driver, and the amplifier, and to connect them through external binding posts. This is understandable considering the large quantity of receivers, using crystal or other types of detectors, being employed at the time tubes came into general use. The Navy, with its limited radio

[4] In 1923 improvements were made which sharpened the wave and eliminated the compensating wave.

[5] This transceiver is graphically described in app. M.

[6] "History of the Bureau of Engineering, Navy Department, During the World War," (Washington, Government Printing Office, 1922), p. 37.

[7] A list of these receivers and their normal usages is contained in app. M.

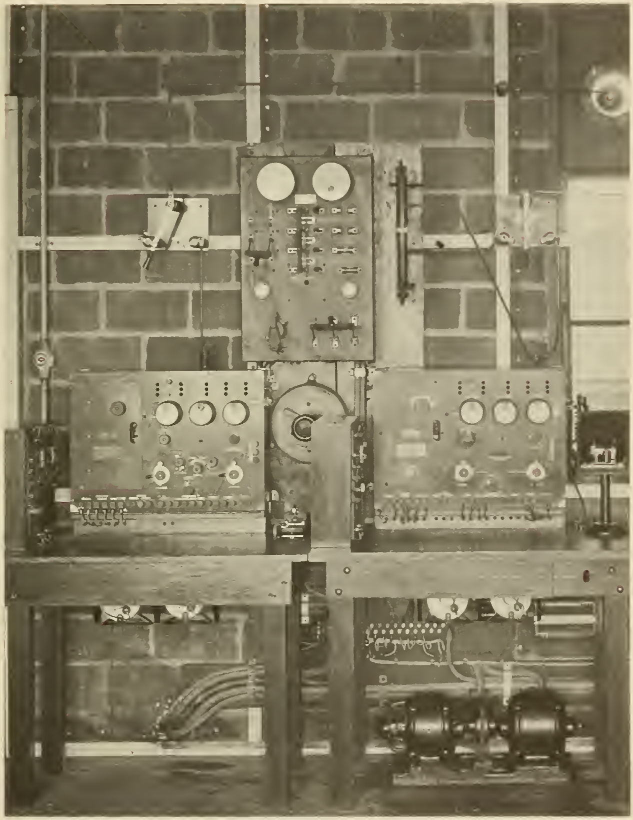

FIGURE 21–1. Dual shore station installation CW 936 radio telephone equipment.

budget, was unable to provide sufficient vacuum tube devices for several years. They were provided ships and stations in small quantities and their use was restricted to the reception of continuous wave signals or for amplifying the weakest signals.

More improvements in radio receiving equipment and techniques were made between 1913 and 1917 than in the previous 15 years. Many of these stemmed from the work of, or the assistance rendered by, naval radio engineers. Except for the complicated patent situation, further improvements would have been realized. The development of military radio equipment by commercial interests was discouraged by the Navy's decision to design and if necessary to develop and build equipment suited to its own particular requirements. The closure of the commercial and amateur stations in 1917 curtailed the market for radio equipment. These factors combined with the patent situation, still further discouraged commercial development.

Between late 1915 and early 1918 a court decision protected manufacturers from infringement suits in the provision of equipment under Government contracts. With this protection, they were extremely willing to manufacture radio equipment of Navy design and under rigid Navy specifications. In 1918 this decision was reversed and the radio manufacturers again became concerned over the possibility of litigation and were unwilling to complete their contracts. The Navy, lacking the manufacturing facilities to produce the large quantities of radio equipment necessary for the prosecution of the war, required the services of the commercial manufacturers. Assistant Secretary of the Navy Franklin D. Roosevelt issued the famous "Farragut Letter" which assured contractors that the Government would assume liability in infringement suits. With this assurance they continued manufacturing the needed equipment.[8]

The burden of the design and development of receiving equipment continued to fall largely to the Navy, with some assistance from the Western and General Electric Cos., and the National Electric Supply Co. This design and development was the responsibility of the Washington Navy Yard where it was assigned as a function of the Radio Test Shop. In 1915 this facility was placed under the direction of Lt. (jg) William A. Eaton, USN, an officer possessing an "especial technical education, an investigator and inventor of high order." [9]

Too little credit has been given Eaton for the work performed by his group which consisted of Gunner T. McL. Davis, USN, Expert Radio Aids Priess, Israel, and Horle, Radio Electricians Shapiro, Carpenter, and Worrel, and Prof. L. A. Hazeltine, consultant. Despite other pressing duties [10] they were able to design and develop superior receiving equipments and to provide commercial companies with ideas which lead to their development.

Early in 1916 it was decided to redesign the type A and B receivers. The specifications for the new receivers were provided to the Washington Navy Yard and to the National Electric Supply Co., of Washington, D.C. The Navy Yard had completed the new designs of these receivers before the National Electric Supply Co. submitted models of their two receivers, the CN 208 and CN 239. It was discovered that the induction coils of these were superior to those used in the Navy designs. Production of type A, 1917, had commenced but was stopped after 40 receivers had been manufactured. Type B, 1917, was not placed into production.[11] Modified specifications were immediately issued and the Navy Yard redesigned and developed their sets, designated the SE 95 and SE 143 receivers. The Navy and the National Electric Supply Co. equipments were comparable. The SE 143 and CN 208 sets which covered the most used frequency

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[8] Infra, Chap. XXXI

[9] Letter, dated 17 Jan. 1915, from G. H. Clark to the Engineer Officer, Washington Navy Yard.

[10] During the period of actual hostilities the shop tested 3,636 receivers, 1,100 amplifiers, 815 transmitters, and 2,835 ancilliary devices.

[11] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 371.

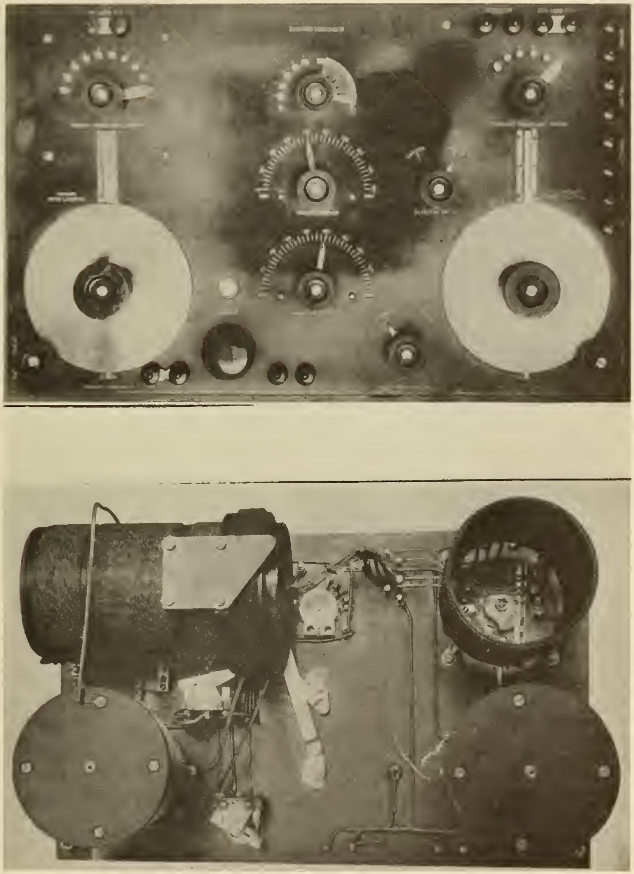

FIGURE 21–2. U.S. Navy-designed receiver, SE 143.

range, 100–1,200 kcs, became the Navy's wartime utility sets. They were manufactured in large quantities by several manufacturers. The SE 95 and CN 239 covered a range of 30–300 kcs. Numerous modifications to both of these equipments were made to meet specific requirements.

Toward the end of 1918 the SE 1220 receiver was designed by the Radio Test Shop. Inductive coupling was used for the first time in Navy-designed equipment. This receiver, which covered the frequency range 45-1,000 kc, contained tuned and untuned secondary coils either of which could be used by proper positioning of a double-pole, double-throw switch. The purpose of the untuned secondary was to provide close coupling between the primary and secondary sets to facilitate initial signal pickup. This receiver was superior to the SE 143, but before it could be placed in quantity production Professor Hazeltine devised his method of neutralizing undesired oscillations. The SE 1420 receiver, embodying this neutrodyne method of reception, was then designed. In this receiver the vacuum tube detector circuit was made an integral part of the receiver, thus eliminating the need of this component as an additional item of equipment. The untuned secondary circuit was eliminated and, by thorough shielding, it was made highly selective and proofed against the pickup of local interferences.

With several minor modifications the SE 1420 became the Navy standard medium-wave receiver and remained in service for many years. Additional receivers were designed upon the same principles, covering other frequency ranges or for special uses in aircraft, or with direction finding equipment. One of these, the SE 1440, designed for use with the radio direction finder, was the first equipment in which the audiofrequency amplifying circuit was an integral part.

The increased reliability of vacuum tubes brought about by the General and Western Electric Cos. made their use as detectors more feasible. Early tube detector units were purchased from De Forest but their construction was not satisfactory and Eaton and his associates, assisted by Western Electric Co., engineers, developed the SE 838. This was soon improved by Navy engineers and designated SE 1071. The growing practice of making the detector circuit an integral part of the receiver soon made these devices obsolete.

Early audiofrequency amplifiers were purchased from De Forest. These facilitated the reception of weak signals but, like his detectors, they were not entirely satisfactory. The Radio Test Shop redesigned his device, making it a two-stage audiofrequency amplifier, designated SE 1000. During the life of this amplifier it underwent six improvement modifications and was Navy standard equipment for years.

The urgent need of high-power amplifiers for reception in aircraft resulted in the development of six-stage amplifiers containing three stages of radiofrequency amplification, followed by a detector circuit, and then two stages of audiofrequency amplification. The first of these completed was the SE 1613 (100–300 kc.). It was immediately improved and redesignated SE 1615 (30—100 kc.). The SE 1617 (18-43 kc.) followed. The SE 1405 (45–150 kc.) was designed for use with aircraft radio direction finders.

The radiofrequency driver was a low-power generator of continuous waves which supplied the local oscillations for modulating incoming continuous wave signals to make them audible. This device was necessary for use with the Navy receivers not employing autodyne reception. Only three types were developed, all of which contained similar circuitry.

Eaton and his assistants, with the aid of Hazeltine, were successful in providing the Navy with receiving apparatus as good as, and in most cases better, than that used by any other nation, and vastly superior to any equipment in commercial use. They also made it possible to procure this apparatus in large quantities at a high production rate and at very low cost.[12]

[12] "History of the Bureau of Engineering, Navy Department During the World War," op. cit., p. 118

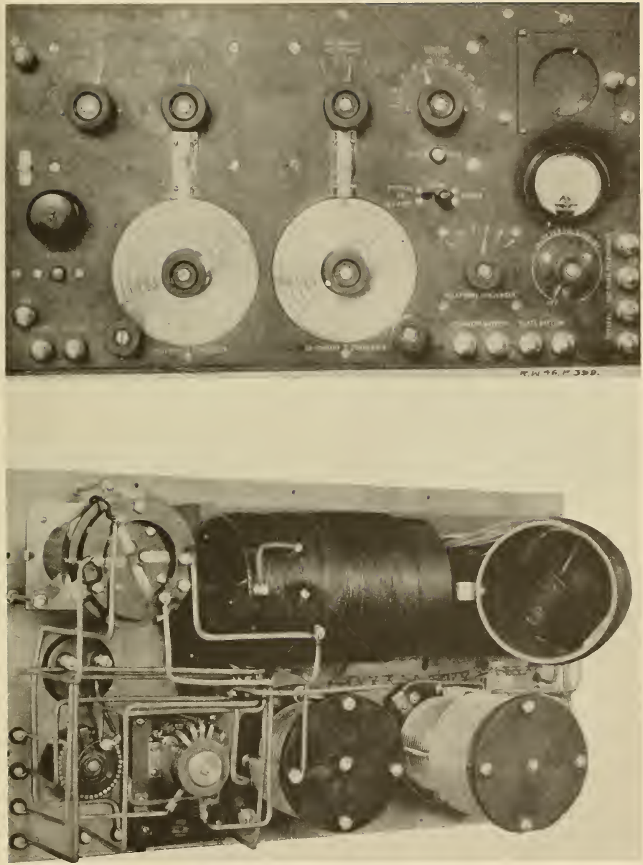

FIGURE 21–3. U.S. Navy-designed receiver, SE 1420.

CHAPTER XXII

The Radio Direction Finder

EARLY INVESTIGATIONS

The directive properties of propagated radio waves were discovered soon after they became used for communication purposes. Numerous persons, including Sir Oliver Lodge, of England; Andre Blondel, of France; De Forest, Pickard; and Stone, of the United States; and Bellini and Tosi, of Italy, had endeavored to develop equipment utilizing these properties.

EARLY U.S. NAVY INTERESTS

Navy interest in the radio direction finder, then called the radiocompass in an effort to stimulate navigational interest, began almost at the time of the initial fleet radio installations. In 1906 the Stone Radio & Telegraph Co., installed a direction-indicating device in the naval collier *Lebanon*, at their expense, for test purposes.[1] The Chief of the Bureau of Equipment addressed a letter to the Secretary of the Navy concerning these tests which stated:

> The Bureau has recently been making experiments with a wireless telegraph direction finder on board the collier *Lebanon*. The results thereon obtained indicate that a development of the system will have a far reaching effect on the safety of vessels at sea, and will possibly play an important part in naval warfare by making it feasible to locate the direction of an enemy's fleet. Indeed the subject is of such importance, in the opinion of the Bureau, that it is deemed advisable, without delay, to thoroughly test out the system on large vessels under sea conditions.[2]

This equipment did not meet the expectations of the Bureau's personnel due to a multiplicity of reasons. Chief among these was that an antenna, fixed in azimuth, was used. This necessitated the swinging of the ship to obtain the maximum signal and the bearing. The absence of an amplifier to increase the intensity of the signal made it difficult to determine the exact time the ship swung through the point of maximum intensity. Little was known of the radio deviation caused by the closed-looped circuits inherent in ship construction, and these deviations were not compensated for and caused large errors in the bearings obtained.

LATER NAVY INTEREST

No further attempt was made to procure direction-finder equipment until 1913. In the fall exercises of that year Hooper endeavored to predict the movements of the opposing exercise force by the simple expedient of comparing signal strengths, and was quite successful in his prediction of the attack hour.[3] Following this, he wrote Hepburn of the results obtained during the

[1] S. C. Hooper, Navy History—Radio, Radar, and Sonar, Recordings, Office of Naval History, Washington, D.C., 31R76.

[2] Letter, dated 17 Oct. 1906, from Chief of the Bureau of Equipment to the Secretary of the Navy, files, Bureau of Equipment, National Archvies, Washington, D.C.

[3] Hooper, op. cit., 17R42.

exercise and recommended that the Bureau investigate the possibility of obtaining direction finders.

By this time both Bellini-Tosi and Telefunken had patented devices for this purpose, and, pursuant to the fleet recommendation, the Bureau purchased one each of these. The Bellini-Tosi apparatus with its large umbrella-type antenna of radial wires about 100 feet in length was installed in the U.S.S. *Wyoming* for tests. The results were most disappointing. Because of the deviation set up by the many closed loops on the ship and the lack of amplification of the extremely weak signals, all transmissions appeared to be generated from the direction of the ship's heading. To the bitter disappointment of the Fleet Radio Officer, and to the great satisfaction of exponents of the trim-appearing ship, the cumbersome equipment was removed and installed at Cape Cod, Mass., for further tests ashore.[4]

The Telefunken equipment was not, in the true sense, a direction finder but an early version of the radiobeacon or homer. It consisted of a mast, approximately 100 feet high with antennas radiating from it spaced 20° apart. Each antenna was connected to the transmitter through a rotating device that shorted out all but one in such a manner that the code for a letter assigned to each aerial would be transmitted sequentially on its assigned aerial. The operator of a receiver picking up the signal determined the particular letter which came in the strongest and by reference to a table of letter assignments could determine roughly the reciprocal of the bearing of the transmitter. Obviously, the closer the receiver to the transmitter the smaller the error. This apparatus was usable for rough navigational purposes but was of no military value since it could not provide bearings of enemy transmissions.[5] It was installed at Fire Island, N.Y., where it provided bearings with errors of about 5° to 10°.

At the end of 1915 bids were advertised for two shipboard direction finders one each for installation in a battleship and a cruiser. The specifications were very definite and difficult to meet. Proposals were received from the National Electric Signaling Co., the Sperry Instrument Co., and the Marconi Wireless Telegraph Co., of America. The guaranteed bid of the latter firm was accepted and the contract was signed on 28 March 1916. The equipment proved to be an improved Bellini-Tosi equipment. In order to comply with the contract provisions, they were installed in the U.S.S. *Pennsylvania* and U.S.S. *Birmingham*, where tests again proved them unsatisfactory. Following this the contract was canceled and the Marconi interests forfeited their bond.[6]

DEVELOPMENT OF A SATISFACTORY METHOD

Dr. Frederick A. Kolster, of the Bureau of Standards, had been earlier employed by the Stone Radio & Telegraph Co., where he became interested in radio direction finding. In 1915 he discovered that a coil of wire wound on a rectangular frame mounted in such a manner that it could be rotated could be used to determine the direction of propagation of radio waves. Using a collector of this type, he found that when the coil was in a plane normal to the incoming waves no current was induced, but when in a plane parallel to them, maximum current was induced. By connecting this loop to a receiver, tuned to the desired frequency, and then rotating it until maximum or minimum signal was received, the direction of the transmitter could be determined by reading the number of degree displacement from the north and south line on a properly installed dial attached to the shaft supporting the coil.[7]

[4] Ibid., 17R43.

[5] Ibid., 31R76.

[6] Ibid., 31R77.

[7] "History of the Bureau of Engineering, Navy Department, During the World War" (Washington, Government Printing Office, 1922), p. 96.

PURCHASE OF RIGHTS UNDER KOLSTER PATENT

Hooper, as Head of the Radio Division, inspected the device and quickly decided that it was exactly what was needed. Kolster was requested to keep it secret, but he advised that he had already discussed it with some of the commercial companies and that one of them had offered him $100,000 in company stock for the instrument. After considerable bargaining he accepted $20,000, retaining the commercial rights upon future release by the Navy. With the agreement of Dr. W. S. Stratton, Chief of the Bureau of Standards, he was employed as a consultant to assist in the adaptation of the apparatus for use aboard ship.[8] After World War I the commercial rights were released to him and were sold to the Federal Telegraph Co., for an undisclosed amount.[9] The Philadelphia Navy Yard was assigned the responsibility for adapting the Kolster direction finder for ship's installations and for further development.[10] Expert Radio Aid E. D. Forbes was placed in charge of the project with Kolster as consultant.

The first equipment constructed was installed there for experimental purposes. Such success was obtained with it that, in November 1916, the Director of Naval Communications requested it remain there as a permanent installation for use in the location of unneutral stations.[11] It was decided to locate 12 additional stations along the Atlantic coast for the same purpose and for the detection of enemy signals should we become embroiled in the war. No consideration was given at the time of the establishment of coordinated groups of three around the major Atlantic ports to provide the accurate fixes required to navigate vessels in restricted waters during periods of low visibility.

[8] Ibid.

[9] Letter, dated 31 Oct. 1922, from the Bureau of Ships to commander in chief, U.S. Pacific Fleet.

[10] These direction finders are described in app. M.

[11] "History of the Bureau of Engineering, Navy Department, During the World War," op. cit., p. 97.

EARLY SHIP INSTALLATIONS

The first adaptation of the Kolster device for ships' installations was for battleships and cruisers. Twenty of these devices were built and installed before the end of 1916. They consisted of a modified version of the Kolser coil, designated SE 74, and a compensating condenser, SE 75, designed by Radio Aid Stuart Ballantine. This condenser, connected between one of the binding posts connecting the coil to the receiver and the ground, made possible the use of the null (minimum signal) method instead of the maximum signal method and increased the accuracy. After installation, the equipment was calibrated to determine the deviation on each target bearing. Prior to the calibration all closed loops had to be bonded to the ship's structure, guns placed in their normal position of train and other movable equipment stored in the usual position. Thereafter, when the direction finder was used, all apparatus had to be returned to the calibration position. In practice, this was uncontrollable, and errors in bearings varied considerably. Compared with present-day equipment it was crude and difficult to use. For example, the reverse bearing could only be eliminated by the inexact and slow process of determining signal intensity.

USAGE PROBLEMS WITH EARLY SHIP INSTALLATIONS

The direction finding equipment did not meet with universal acclaim. Many of our senior officers were more devoted to the "hits-per-gun-per-minute dogma," the "big? payoff" for the individual ship commander, than to any innovation which would assist in the detection of the enemy and facilitate in concentrating the greatest possible number of ships at the scene of action in the shortest period of time. To worsen the matter, there was a tendency on the part of all officers to be diffident about things they did not understand. Misnaming this equipment "radiocompass," which it was not, added to their lack of comprehension of its importance, and caused them to label it a "new-fangled device" to replace old and proven methods of navigation. The sole purpose of a radio direction finder installation is to provide the means of determining the bearings of a radio transmitter emitting signals. Whether these bearings be used to determine the position of a distressed ship, an enemy, or an aid in the navigation of ships and aircraft is not a function of the equipment. Bullard, in command of the U.S.S. *Arkansas* during 1917, wrote Hooper concerning the attitude of the officers. He stated that he found little enthusiasm concerning the compass and that he believed they did not recognize its possibilities and, until they were educated concerning such possibilities, their natural conservatism would militate against its use.[12]

DESTROYER DIRECTION FINDERS

After this country entered the war, our naval officers adapted themselves to innovation more quickly than had been their wont. Allied shipping was being depleted by the German submarine campaign and this method of warfare required ingenuity in the offense.

While the equipment was being installed on the battleships and cruisers, design of sets with smaller coils for destroyers was proceeding. In May 1917, Austin, of the Navy Radio Research Laboratory, advised that the addition of a single vertical wire to the direction finder antenna system would eliminate one of the two nulls, thereby giving positive direction of the transmitting target. This was incorporated in the SE 995 destroyer direction finder. This equipment utilized a 20-inch coil of two windings and the vertical antenna connected to an SE 998 receiver and a SE 1000, two-stage audio-frequency amplifier. This was ready for installation by the summer of 1917 and was greatly superior to the earlier equipment. It was fitted in all destroyers available in continental navy yards and shipped to Brest for installation in those operating from that base.

The young destroyer commanders developed plans utilizing this equipment for locating enemy submarines; effecting concentrations for hunter-killer operations; and for assembling and escorting of convoys in thick weather. They were so successful that by early 1918 the German Submarine Service was completely demoralized and ineffective.

THE RADIO DIRECTION FINDER IN THE WAR ZONE

The European belligerents made no endeavor to equip their men-of-war with direction finders, but both England and France established shore systems. England was using its system to track German ships and submarines to great advantage, particularly since the German naval authorities has not been properly indoctrinated in communications security.

Upon our entry into the war, the Navy established an operating base at Brest, France, and most of the logistic supplies from this country entered that port. The Germans concentrated submarines in the Bay of Biscay in an effort to cut this line of supply. Adm. H. B. Wilson, USN, who commanded the U.S. Naval Forces in that area, directed the establishment of three direction-finder stations to cover the Bay of Biscay. These stations were connected with wire communications to the flagship at Brest. German submarine commanders, unaware of the use of direction finders, continued the unrestricted use of radio and allowed themselves to be constantly tracked. Convoys were easily diverted to avoid them. Moreover, in the foggy weather that abounds in the Bay of Biscay the convoys were tracked and directed in or out of port without delay.[13]

[12] Hooper, op. cit., recording 32R78.

[13] Hooper, op. cit., recording 32R78.

IMPROVEMENT OF RADIO DIRECTION-FINDER EQUIPMENT

Late in 1918, the SE1440 receiver became available. It was especially designed by the Washington Navy Yard for use with direction finders and integrally contained three stages of audiofrequency amplification. It was fitted with a "compass receiver" switch that permitted instant connection to the compass coil or to an ordinary antenna. Together with a 515A coil system and an SE 1762 compensating condenser, it became the model DA shore direction finder. The shipboard installations SE 74 and SE 995 were basically improved by refitting them with the SE 1440 receiver and a newly designed coil, SE 1512. These equipments were much simpler in operation and maintenance and were more accurate.

ESTABLISHMENT OF NAVY SHORE DIRECTION-FINDER SYSTEM

Despite the enormous merchant ship program of the United States, the submarine campaign had so depleted Allied shipping that every hour lost by a convoy at sea due to poor visibility or to delay in port was of great seriousness. Additionally, every day they kept at sea because of their inability to enter fogbound ports rendered them that much more vulnerable to the submarine menace.

In early 1918 the Chief of Naval Operations, concerned with the delays of transports by weather conditions, directed his Planning Committee to study the subject and endeavor to eliminate these delays. The Committee recommended the establishment of direction-finder stations in groups of three around the approaches to the harbors of Boston, New York, and Charleston, and the entrances to the Delaware River and the Chesapeake Bay. One station of each group would operate as the master or controlling station and control a transmitter at a distant station by landline. The two "slave" stations would telegraph their bearings to the master, where the plotting would be done and fixes or bearings transmitted to the convoy commander. This was approved, and in June 1918 the sites for these stations were selected.[14] Urgent requirements for new ship installations and improvement to existent ones delayed the completion of these shore stations. At the date of the armistice not one of them was in operation. On 26 December the New York group was placed in operation in time to be used by our battleships returning from their duty with the British Fleet. The remaining groups were commissioned rapidly thereafter and hastened the operations of the troopships returning our soldiers from overseas. Their successful operation resulted in the establishment of groups at all important ports in the United States, on the Great Lakes, and at dangerous navigational points along our coasts.

[14] Hooper, op. cit., recording 32R79.

CHAPTER XXIII

Development of Aircraft Radio Equipment

PROLOG

A study of various articles, statements, and requisitions for equipment leads the writer to believe that the operational use of aircraft radio equipment during World War I has been overly glamourized and distorted. However, it was a period of intensified research and development of equipment for that purpose. Had the war continued longer, it is most probable that operational use of aircraft radio would have increased rapidly.

Following the Maddox experiments[1] there is no record of further action to provide radio equipment for aircraft until about April 1915 when four Foot-Pierson, battery powered, spark transmitters were purchased for fitting into aircraft for controlling the fall of shot. With their limited range of 5 miles, they proved unsatisfactory for that purpose.[2]

When Hooper became the Head of the Radio Division, one of his first acts was an endeavor to interest the Aeronautical Division, then a part of the Bureau of Steam Engineering, in equipping aircraft with radio. He was not very successful in this. Our early naval aviators were rugged individuals, flying underpowered aircraft difficult to maintain in a safe altitude even without the added weight of radio equipment. The additional tasks of mastering the telegraphic code and operating the equipment while flying the plane did not appeal to many of them. However, Hooper rightfully believed that the value of scouting planes was lessened unless they could report enemy contacts by radio and remain on station to provide continuing information. Likewise, spotting planes would be of little value unless they could continuously radio corrections in range and deflection.

Hooper's next action was to direct the Naval Radio Research Laboratory to prepare a study of the probable range of an aircraft radio transmitter of a weight not exceeding 100 pounds. On 13 May 1916 Austin submitted the following report:

1. Antenna wires on wings of plane, 7 feet apart. Weight of set, 300 pounds; Distance, 10 miles.
2. Trailing wire 50 feet long, plane as counterpoise. Weight of set, 100 pounds; distance, 15–30 miles.
3. Trailing wire 400 feet long, plane as counterpoise. Weight of set, 100 pounds; distance 75–100 miles.

PRE-WAR EQUIPMENT

On the same day Hooper forwarded this information to the Aeronautical Division. After waiting a reasonable time, and having received no reply, he discussed the problem with the Chief of the Bureau of Steam Engineering, Rear Adm. R. S. Griffin, USN. Griffin was sympathetic and directed him to procure the necessary equipment.

Lt. E. H. Loftin, USN, whose brilliant work in radio engineering had brought him to prominence, was ordered to the Radio Division to assist in the preparation of the necessary specifications. When completed, they listed the following requirements:

[1] Supra., ch. XIV.

[2] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., G. H. Clark, "Radio in War and Peace," p. 194.

- Weight not to exceed 100 pounds;
- Fit into an aircraft space of dimensions which were provided;
- Antenna to be of trailing wire type, 200 feet long and provided with reel, brake, weight, and other necessary appurtenances;
- Transmitter to provide for telegraphic operation but could include radio telephone capability;
- Transmitter range to be 100 miles or more; and
- A working model to be submitted prior to contract award.

The initial requisition, dated 25 July 1916, was for 75 sets. This number was chosen because it was believed that the development work would be so costly that manufacturers would not be interested unless sufficient incentive was provided.[3] It was expected that 2 or 3 companies might be interested but, to the surprise of all concerned, 13 submitted bids, and of these seven submitted models. A memorandum from Loftin to Clark stated:

> The De Forest Company and the Western Electric Company offered sets for code and voice; the Marconi Company, E. J. Simon, F. Lowenstein and the Wireless Specialty Apparatus Company made provision for code only. The successful bidders were the Marconi Wireless Company of America, the De Forest Radio Telephone and Telegraph Company, the Western Electric Company, and the Sperry Gyroscope Company.[4]

Hooper in his memoirs stated:

> The award was made to four bidders, the bids split evenly and then I purchased two or three of the other samples which had novel features but which were not by the lowest bidders. I don't recall exactly who got the awards, — as I recall it was E. J. Simon and Company, Marconi Company of America, Lowenstein and one or two others. I cut the number of sets down from 75 to 50 when I found we didn't have 75 airplanes.[5]

In a paper presented before the New York Chapter, Institute of Radio Engineers, on June 1919. T. Johnson, Jr., Expert Radio Aid, Navy Department, stated that the sets purchased at that time were the Marconi spark set, CM 295; the Sperry vibrator arc set, CS 350, designed by Dubilier; and the De Forest vacuum tube set, CF 118. He further stated that the latter apparatus was the first radiotelephone equipment installed in aircraft.[6] The contract records of the Navy Department and the assignment of type numbers by the Bureau indicate the following purchases of aircraft radio sets at this time:

De Forest	16	CF 118,[7] CF 349[8]
American Marconi	15	CM 295[9]
Sperry Gyroscope Company	15	CS 350[10]
E. J. Simon	15	CE 615[11]

[7] Contract NPO 918, 16 Feb. 1917.

[8] Contract 28308 NSA, 21 Dec. 1916.

[9] Contract 28309 NSA, 21 Dec. 1916.

[10] Contract 28310 NSA, 21 Dec. 1916.

[11] Contract 28386 NSA, 1917.

The context of Hooper's statement indicates that he was speaking from memory. The contract for purchases are most probably correct, although they could have been modified after being awarded.

The Simon set, designed by Israel,[12] was the only one of these prewar purchases that showed promise. It was powered by a wind-driven generator, mounted on a wing of the aircraft, that could be braked when not required. A completely insulated antenna reel permitted the tuning of the antenna circuit while the 500-watt transmitter was in operation by varying the length of the trailing antenna. The receiver used one three-element vacuum tube and a regenerative circuit. Installed, the entire equipment weighed approximately 100 pounds. During the tests of this equipment signals were transmitted over 150 miles.[13] Early in 1918 an additional 100 sets were purchased from Simon.[14]

Most of the sets manufactured by De Forest were transferred to the Army Signal Corps for use in developing equipment for

[3] Ibid., p. 197.

[4] Ibid.

[5] S. C. Hooper, "History of Naval Radio, Radar, and Sonar," Office of Naval History, Washington, D.C., recording 21R51.

[6] Proceedings, Institute of Radio Engineers (vol. VIII, No. 2, February 1920), pp. 6–7. T. Johnson, Jr., "Naval Aircraft Radio."

[12] Israel was a naval expert radio aid during World War I.

[13] "History of the Bureau of Engineering, Navy Department, During the World War," Washington, Government Printing Office, 1922, p. 120.

[14] U.S. Navy contract 35238, dated 22 Jan. 1918.

the Army Air Corps, which desired to use voice equipment.[15] Later, when we became an ally of the British, some of the Marconi and Sperry equipments were delivered to them.[16]

ESTABLISHMENT OF NAVAL AIRCRAFT RADIO LABORATORY

After these contracts were awarded, Loftin was transferred to New Orleans, La., as District Communication Officer to supervise the work of the Aircraft Radio Laboratory, established in the summer of 1916, at the Naval Air Station, Pensacola, Fla. This Laboratory, under the direction of Expert Radio Aid B. F. Meissner, was charged with the testing of the equipment procured under these contracts. In addition to this function, Meissner was directed to study and devise methods for providing intercommunication between crewmembers, reduction of ignition and other noises caused by a plane in flight, and the adaptation of the radio direction finder to fit aircraft requirements.[17]

DEVELOPMENTS OF NAVAL AIRCRAFT RADIO LABORATORY

Communication between crewmembers of early aircraft by the normal means of conversing was prevented by the noises of the motors and wind rush. The Pensacola Laboratory first developed equipment of the voice-tube type with suitable helmet and appurtenances. This was clumsy and after the development of satisfactory radiotelephone equipment it was supplanted by an intraplane telephone system which also allowed the pilot telephonic communication with other planes.[18]

The elimination of ignition and other electrically redundant generated noises from the receivers presented a problem not easily solved. The best solution, that of shielding the entire ignition system, was unacceptable to the aviators because it reduced its efficiency. The next best method was the use of suppressors in the spark-plug leads. This was also unacceptable to the aviators because it reduced the intensity of the ignition spark. Under these limitations, the only thing which could be done was to bond and ground all parts of the plane structure which formed closed loops, and to accept the ignition noises. In his memoirs Dr. Taylor stated in 1947: "The conquest of ignition disturbances in planes is not completed, even at this time." [19]

In adapting the radiocompass to aircraft, ignition noises prevented the use of the minima method of obtaining bearings. Dr. James Robinson, of Andover, England, devised a method of utilizing two loops on the same rotating frame, the planes of which made an angle of approximately 60° with each other.[20] By first connecting one loop and then the other to the receiver, by means of a manually operated switch, maximum signal could be obtained in either loop by rotating the frame. The bearing was obtained by rotating the loops so that the strength of the received signal was the same regardless of the position of the switch.[21]

A trailing-wire antenna system had been designed and patented by Maj. Harry Mack Horton, Army of the United States, prior to his entry into the service. The Laboratory at Pensacola had adapted this to flying boats by improving the braking, the dielec-

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[15] "Radioana," op. cit., Clark, "Radio in War and Peace." During World War I there was no Army requirement for long-range planes; therefore, they could accept the short-ranges resulting from the use of voice modulation.

[16] Hooper, op. cit., recording 21R52.

[17] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 200.

[18] Johnson, op. cit., pp. 7, 127.

[19] A. Hoyt Taylor, "Radio Reminiscences: A Half Century," U.S. Naval Research Laboratory report, p. 113.

[20] U.S. Patent No. 1,435,941, dated 21 Nov. 1922.

[21] Taylor, op. cit., p. 106.

tric quality of the reel, and by adopting a type of antenna wire sufficiently brittle to snap upon entanglement with buildings, masts, or other objects before interfering with the stability of the plane. The latter was a necessary improvement, but it often resulted in the streamlined weight at the trailing end of the wire snapping off and falling to earth. Once one plummeted through three floors of a house and imbedded itself in the concrete floor of the basement. Another time one barely missed a policeman and flattened itself on the pavement at his feet. Lt. C. B. Mirick, USNR, later devised a hollow shell weighted with fine shot. If this became detached from the antenna, the shell would open, spilling the shot which would fall with less chance of causing serious damage or loss of life.[22] Horton was later granted $75,000 for the infringement of his basic patent by the Government.

The spark transmitters of the flying boats had to be fitted within the hull in the same space that held the gasoline tanks. In order to prevent the spark from igniting the ever-present fumes, Meissner designed an enclosed spark gap which eliminated the danger.

WARTIME REQUIREMENTS

Shortly after our entry into the war, a decision was reached to strengthen the naval air arm. Requirements called for long-range aircraft for antisubmarine, patrol, and convoy duties, and shorter range ones for scouting and spotting fall of shot. Communication equipment of different types were necessary for the long- and short-range planes. It was necessary that this equipment be operated by aviators with a minimum of training. Fortunately, they were required to have an operating proficiency of 18 words per minute prior to the completion of their flight training.

[22] Taylor, op. cit., p. 112.

The Navy program was based upon the use of a single-engine flying boat for the short-range purposes and a twin-engine flying boat and dirigibles for the longer range duties. Both planes were to utilize Liberty engines. Altogether, 1,185 single-engine and 864 twin-engine craft were contracted for, and it was necessary that they be equipped with radio as they came off the production lines during 1918.[23] Spark transmitters were considered essential to provide the ranges desired for dirigibles and the flying boats, while tube transmitters would suffice for the single-engine craft.

The development of satisfactory standardized radio equipment and its production in large quantities in a short time, presented the Bureau with one of its most difficult wartime tasks. It was essential to combine compactness, light weight, and simplicity of manufacture with ease of control, watertightness, and ruggedness. Moreover, the configuration of the craft was a controlling factor in the final encasement of the apparatus. Development was slowed by lack of aircraft for radio test purposes. Early in the development work it was discovered that it was necessary to employ pilots who were sympathetic with radio investigations and who could visualize the extended uses of aircraft fitted with reliable communications.

Faced with the necessity for providing equipment and fitting it into the aircraft under contract, the Bureau requested all possible manufacturers to submit aircraft sets for test. Spark transmitters were submitted by the E. J. Simon Co., the National Electric Supply Co., the International Radio Telegraph Co., and Cutting & Washington. The General Electric Co., the Western Electric Co., the Marconi Wireless Telegraph Co. of America, the General Radio Co., and the De Forest Radio Telegraph Co. submitted vacuum tube transmitters.

[23] "History of the Bureau of Engineering, Navy Department, During the World War," op. cit., p. 138.

WARTIME DEVELOPMENT OF AIRCRAFT EQUIPMENTS[24]

On 1 January 1918 the Naval Aircraft Radio Laboratory was moved to the Naval Air Station, Hampton Roads, Va., where flying boats of the two standardized types were available. Standardized antenna systems were designed and developed for both types and the measurements of their constants accomplished. Experiments directed toward standardized installations were made. The equipments submitted by the manufacturers were tested and those described hereafter were approved for service use as standard equipment.

The CQ 1115, 200-watt, and the CQ 1111, 500-watt, spark transmitters were designed, developed, and manufactured by the International Radio Telegraph Co. They were powered by a wind-driven generator which, with the main element of a rotary gap transmitter, was contained in a streamlined case mounted on a wing of the plane. A tuning variometer was located in the cockpit. The 200-watt transmitter weighed 65 pounds and had a range of 100 miles. The 500-watt unit weighed only 20 pounds more and had a range of almost 1,500 miles when received by a shore radio station and 500 miles when received by a ship. These were the most satisfactory spark transmitters developed for use in aircraft. The CQ 1115 was also supplied to the Army Signal Corps. The complete transmitting equipments installed in the boats and utilizing these basic elements were designated SE 1300 and SE 1310, respectively.

The CP1110 (later modified and designated CP 1110A) transmitter was designed, developed, and manufactured by Cutting & Washington. This impact excitation type transmitter was designed for transmission on the single frequency of 800 kc. Installed, it weighed 77 pounds and was capable of transmitting to shore stations for a distance of 200 miles. It was powered by a Crocker-Wheeler, wind-driven, alternating current generator mounted on one of the wings of the aircraft. It was used with other components to provide a complete aircraft transmitting system, designated SE 1320.[25]

The CN 1105 spark transmitter, powered by a wind-driven, inductor-type alternator, was developed and manufactured by the National Electric Supply Co.[26]

The CW 1058 was a low-powered radiotelephone transceiver manufactured by the Western Electric Co. It was a modification of similar equipment that had been accepted by the Army and included intraboat telephone equipment. One hundred and two sets were contracted for on 4 December 1918, at a cost of $66,000.

The Marconi Co. manufactured the first large order of tube transmitters. Their initial bid for the manufacture of 350 SE 1100, Navy-designed, 200-watt transmitters was rejected because it was considered to be exorbitant. They were then directed to manufacture them on a cost-plus-10-percent basis.[27] The *"History of the Bureau of Engineering During the World War"* states that this was a Marconi-designed transmitter.[28] Clark describes it as Marconi developed.[29] It was similar to CG 1130. Taylor states: "This set was able to work continuous-wave telegraph, with a theoretical range of 150 miles, and voice communication with a range of 60 miles. . . This set gave us lots of trouble and was never particularly reliable, although when in first-class condition, it would operate and the range obtained was very good." [30] Installed, including all components and a receiver, this equip-

[24] These equipments and their normal usages are listed in app. M.

[25] U.S. Navy contract 33396 and NSA requisition 757 dated 7 Dec. 1917 to Cutting & Washington for 20½-kw. commercial-type sets with receivers, antenna, and Chafee gap, $30,000.

[26] U.S. Navy contract 33258 dated 3 Dec. 1917 to National Electric Supply Co. for 50 aeroplane sets.

[27] U.S. Navy contract 2916-18; June 13, 1918; Marconi Wireless Telegraph Co. of America; 350 200-watt flying boat transmitters, SE 1100.

[28] "History of the Bureau of Engineering, Navy Department, During the World War," op. cit., p. 122.

[29] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 314.

[30] Taylor, op. cit., p. 114.

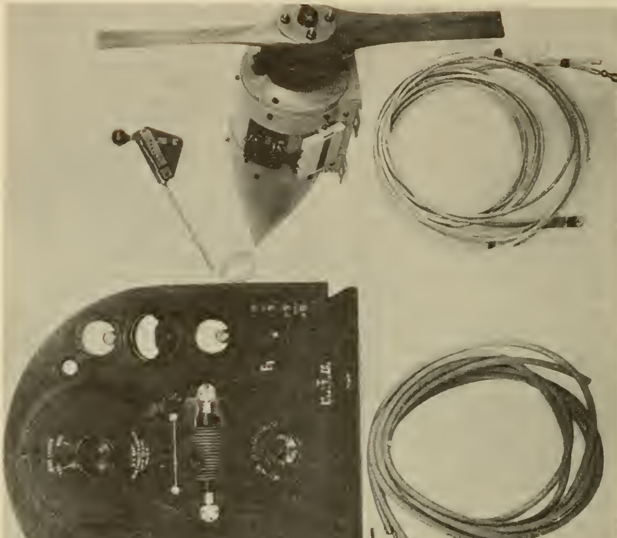

FIGURE 23–1. Aircraft spark transmitter, SE 1300, trailing antenna assembly, transmitter, wind-driven generator.

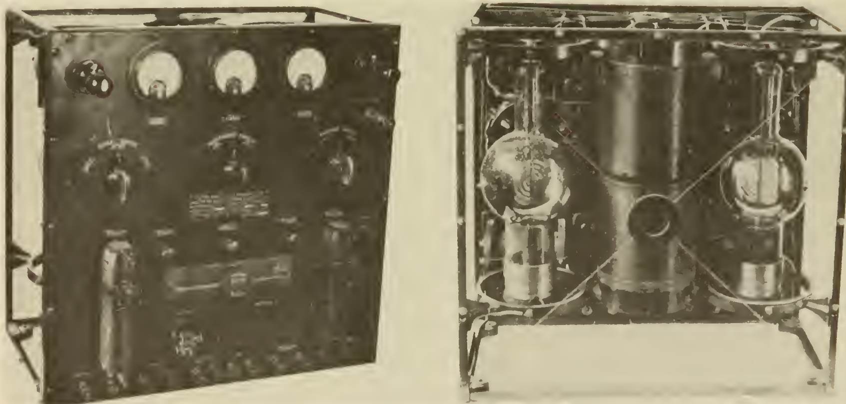

FIGURE 23–2. Aircraft vacuum tube transmitter, SE 1100.

ment weighed approximately 210 pounds. The transmitter used two large General Electric Plyotron tubes, one as an oscillator, the other as a modulator. It was powered by a battery and a dynamotor, but it was difficult to keep the batteries charged. Tone-modulated telegraph transmission could be used. By erecting a small telescope mast, normally stored in the tail of the plane, battery-powered transmissions could be made while on the water.

CG 1104, a 50-watt vacuum tube transmitter, powered by a wind-driven generator and dry batteries; CG 1104A, which was the same as CG 1104 except the dry battries were eliminated; and CG 1130, a 250-watt transmitter, similar to the SE 1100, were designed and manufactured by the General Electric Co. The CG 1104A weighed 50 pounds. It had a range of 30 miles and was used primarily for spotting the fall of shot. The CG 1104 was used in the single-engine flying boats and as an auxiliary transmitter in the larger flying boats. It had a range of 100 miles. The CG 1130 had a telephone range of 200 miles and a telegraph range of approximately twice that distance. It was used in large flying boats and dirigibles. One hundred CG 1104A, 100 CG 1104, and 10 CG 1130 transmitters were purchased.[31] When combined with other components to provide complete aircraft radio transmitting systems, the CG 1104A was designated SE 1340, and the CG 1134 the SE 1380.

Clark mistakenly lists these transmitters as the SE 1340 for single-engine aircraft and SE 1370 and SE 1390 for larger flying boats and dirigibles.[32] The contract for these Navy adaptations of General Electric equipment was dated 9 October 1918 and amended in 1921. It was designed to secure improved equipment resulting from the increased capabilities of manufacturers in providing higher quality vacuum tubes with more constant operating characteristics. Before these equipments were completely developed, better equipment had been designed and developed by naval personnel and only a small number was purchased.

In the summer of 1918 Comdr. H. P. LeClair,[33] USN, who had relieved Hooper as Head of the Radio Division, became concerned about the slow progress being made at the Laboratory at Hampton Roads. In an endeavor to bolster the program, Taylor, now a lieutenant commander, was detached from duty as Transatlantic Communication Officer and ordered to head the Laboratory. In a further endeavor to strengthen the Laboratory, plans were made to move it to the Naval Air Station, Anacostia, D.C. This was accomplished in the fall of 1918.[34]

Prior to moving from Hampton Roads the Laboratory was service-testing the CG 4050, a component of the SE 1390. The General Electric Co. sent their representative, Mr. E. M. Kinney, to assist in these tests being made in one of the large flying boats. One day the weather was bad and the boat was forced down in rough seas by engine trouble about 10 miles offshore. Upon landing, a hole was torn in the bottom and the hull filled rapidly, sinking to the lower wing. The crew and the testing personnel, except Kinney, scrambled up on the wing. He finally emerged from about 6 feet of water struggling with the transmitter which, being the only model, he was determined to save. Again he dived into the hull and disconnected and salvaged the dynamotor. The plane crew had been unable to transmit an emergency message; therefore, no one at Hampton Roads was aware of their plight. Shortly thereafter the lower wing became waterlogged and went under. The luckless people scrambled to the upper wing with the salvaged equipment. Things looked pretty black; no one was in sight; the weather was worsening and be-

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[31] U.S. Navy contracts 39850 and 40836, dated June 28, 1918.

[32] "Radioana," op. cit., Clark, "Radio in War and Peace," p.

[33] LeClair was born in and appointed a midshipman from Wisconsin. He graduated from the Naval Academy in 1909. He relieved Hooper as head of the Radio Division for about 9 months in 1918. He retired as a commander on 30 June 1937. During World War II he returned to active duty and was promoted to captain.

[34] Taylor, op. cit., pp. 101, 120.

coming colder. At this point Kinney, cold, shivering, and with chattering teeth, remarked:

Well boys, this looks like the finish, but if I have to go, I am glad I am going in such darned good company.

Half an hour later a fisherman hove into sight. Frantically they signaled him and finally attracted his attention. He took them ashore where they could telephone the station for a boat. Arriving after dark, Kinney remembered that he had left the dynamotor on the other side of the river. He could not be persuaded from immediately returning to procure it. The transmitter later passed the tests and became a component of the SE 1390.[35]

After the laboratory was moved to Anacostia, its staff was increased by several radio engineers and it was assigned the additional functions of design and development of complete aircraft radio systems. Two transmitters, the SE 1375 and SE 1385, which later became the backbone of naval airborne communications, were designed and developed. Both of these produced a clear 500-cycle note and neither was voice modulated. The SE 1375, 20 watts, which used four three-element tubes and operated on frequencies between 570 and 750 kc., was designed by Mr. F. B. Monar for use in small aircraft. The SE 1385, 500 watts, which used two 50-watt three-element tubes and covered the frequency range, 300–600 kc., was designed by Mr. L. A. Gebhard for use in large flying boats. One of the first radioteletype transmissions from aircraft to ground was made utilizing the SE 1385. It also became the transmitting component of the first aircraft radio transmitting system given a model designation, the GA.

It was difficult to procure receivers of commercial design and development rugged enough or shielded adequately enough for use in aircraft. Since Eaton and his assistants at the Washington Navy Yard were producing excellent designs of receivers for other purposes, the Bureau directed the yard to design receivers for aircraft.

[35] Ibid., pp. 116–117.

In less than 2 weeks after receipt of the directive, the SE 950 receiver was designed, the model built, minor changes made, and then tested. It was so good that, for many years, it was the best aircraft radio receiver in the naval service.[36] It consisted of an inductively coupled three-element vacuum tube receiver, covering the frequency range 125–1,000 kc., provided with static tube coupling for regeneration and oscillation, and two stages of audiofrequency amplification. It is of interest that this was the first receiver ever designed with the amplifying circuits as an integral part. It was also equipped with the proper switching and compensating inductances to permit it to be used as a component of their aircraft direction-finder equipment.[37] It was manufactured by the National Electric Supply Co.[38] and the Washington Navy Yard.[39]

After completion of the development of the SE 950, Eaton and his group designed the SE 1414. It consisted of a conductively coupled receiver, covering the frequency range 300–1,500 kc., with inductive tube coupling to produce regeneration and oscillation. The individual tubes were not provided with shock mountings but the entire receiver was mounted in a rubber suspension. It was manufactured by the Westinghouse Electric & Manufacturing Co. and the Washington Navy Yard.

The need for greater amplification of signals received in aircraft led to the Washington Navy Yard design and development of the SE 1405 amplifier with three stages of radiofrequency amplificaion, a detecting circuit, and two stages of audiofrequency amplification. This was followed by the development of an entire family of such devices covering the usable frequency range. The best of these developed for use with aircraft direction-finder equipment was the

[36] "History of the Bureau of Engineering, Navy Department, During World War," op. cit., p. 122.

[37] Ibid., p. 123.

[38] U.S. Navy contract 25659, 26 Jan. 1918, to National Electric Supply Co., for 321 SE 950, $99,510.

[39] Job order 12-Z-2252, 7 Feb. 1918, for 25 SE 950, $9,530.33.

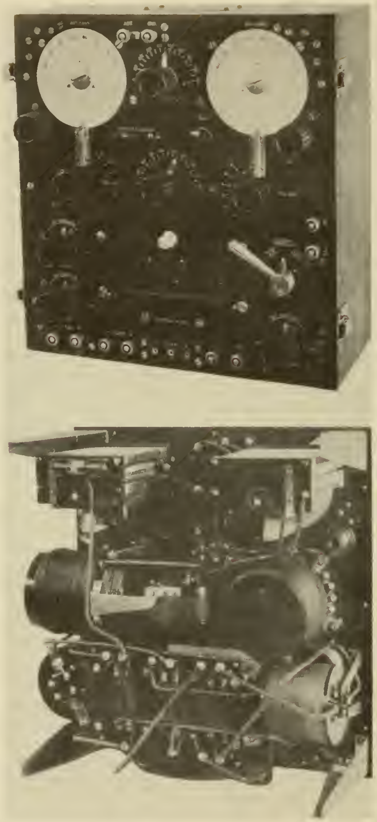

FIGURE 23-3. Aircraft vacuum tube receiver, SE 950.

SE 1605B, an improved version of the SE 1405. It was manufactured in large quantities by the General Electric Co.[40]

In early types of aircraft the severe acoustic disturbances caused by the combination of wind rush and motor and vibration noises necessitated that all crewmembers wear a helmet containing a headset for intercommunication. Several helmets had been designed, all of which produced pressures upon the wearer's head, resulting in violent headaches from prolonged use. The first adopted as standard by the Navy, the CW 1113, was designed and manufactured by the Western Electric Co. This was very unsatisfactory and was supplanted by a Western Electric redesign, temporarily accepted by the Army, and fairly satisfactory for flights of short duration. Meissner, while at Pensacola, redesigned this helmet by replacing the Western Electric ear cups with solid rubber ones. This was designated the SE 1981 helmet, but it also proved unsatisfactory for prolonged use. Meanwhile, Western Electric redesigned the helmet a second time and produced the Army-type HS–2 which was also found unsatisfactory by Navy tests. The Aircraft Laboratory was immediately directed to design a helmet that could be worn indefinitely without pain. This action occurred almost simultaneously with the adoption of the SE 1981 as the temporary standard as evidenced by the designation, SE 2000, included in the directive. However, it was not until after the Laboratory was moved to Hampton Roads and placed under Taylor that a design meeting the requirements was submitted. It was produced by the combined efforts of Taylor, Lt. (jg) W. R. Davis USNR, and Ens. C. D. Palmer, USNR.[41]

This helmet was made of soft leather lined with flannel with the central rear seam left unsewed in manufacture to permit individual fitting. The earpieces were enclosed in deep, soft rubber cups of less depth at the back of the ear, where continued pressure is unbearable. The cups were held tightly against the head by a strap running around the head and back of the neck instead of by the previously used uncomfortable chinstrap. The chinstrap was utilized only to bring the forward edges of the helmet close to the face and to tighten the lower portion of the helmet. A flannel-lined cape at the bottom of the helmet, when buttoned within the flying clothes, prevented entry of wind and noise at that point. It proved extremely satisfactory under service conditions and was worn continuously by the crew of the dirigible C–5 during its 36-hour flight to St. Johns, Newfoundland.[42]

During the early tests of the De Forest radiotelephone equipment, it was found necessary to develop a microphone which would balance out the terrific noises generated under flying conditions. While at Pensacola, Meissner conceived the idea of mounting the diaphragm so that both sides would be exposed to the vibrations from extraneous noises, but only one side would be affected by the directional vibrations set up by speaking into it. He failed to make a satisfactory design. Several companies experimented with his idea and in 1918 the Magnavox Co., assisted by the Aircraft Radio Laboratory, succeeded in the construction of a satisfactory device, the SE 4005.[43]

AIR STATION RADIO EQUIPMENT DEVELOPMENT

The improvement in aircraft radio equipment, with consequent longer ranges, produced a requirement for air station continuous-wave transmitting equipment usable for either radiotelephony or telegraphy. The contract for the development of this equipment was given to the General Electric Co. Just after the termination of hos-

[40] U.S. Navy contract N–5068, 9 Oct. 1918, to General Electric Co. for 275 SE 1605B aircraft amplifiers.

[41] "History of the Bureau of Engineering, During the World War," op. cit., p. 221; Johnson, op. cit., pp. 109–110, 139.

[42] Ibid.

[43] Johnson, op. cit., p. 48.

tilities a model was submitted for service testing. All elements of this unit, except the modulating amplifier and the motor generator, were in one encasement. All meters and essential controls, including a switch for instantaneous shifting to any of five frequencies, 135, 190, 320, 350, and 500 kc., were installed on the front panel. Six vacuum tubes were used, three as oscillators and three as modulators. During tests it delivered 750 watts to the antenna and gave a reliable radiotelephone range from shore to aircraft of over 200 miles. Provisions were made for remotely controlling the transmitter so that the air station commanders, using regular telephone lines, could utilize the equipment from their desks. On 12 March 1920 Secretary Daniels, seated in his Office, conversed with Lt. Harry Sadenwater, USNR, in a flying boat 70 miles away. Regular telephone lines connected the Secretary's telephone with the transmitter at the Washington Navy Yard. Reception of the aircraft radiotelephone transmission was received at the same place, then amplified by two audio stages and carried over the telephone wires to the Secretary's Office.[44] This was a very satisfactory transmitter and proved to be the prototype of the broadcast transmitter of the "twenties." With some minor modifications, it became a component of the model TD shore-station transmitting equipment.

RADIO AND THE TRANSATLANTIC FLIGHT

During the war a decision was reached to design, develop, and construct a flying boat capable of crossing the Atlantic via Newfoundland and the Azores. While this project was not completed prior to the termination of hostilities, the excellent progress which had been made indicated it could be satisfactorily completed. Therefore, the project was continued and four type NC planes were constructed and satisfactorily tested. At 1000, 8 May 1919, three of these, the NC–1, NC–3, and NC–4, with Comdr. J. H. Towers, USN, commanding the NC–3 and the flight, took off from Rockaway Beach, Long Island, on their historic effort to fly across the Atlantic. Towers had originally decided to eliminate all radio equipment to decrease weight during this flight. Hooper was able to convince him that this would be an error.[45] Tower's radio officer was Lt. Comdr. R. A. Lavender, USN, Head of the Aircraft and Radio Compass Sections of the Radio Division. Lt. Comdr. P. N. L. Bellinger, USN, commanded NC–1, with Sadenwater as radio officer. The NC–4 was commanded by Lt. Comdr. A. C. Reed, USN, and his radio officer was Ensign H. C. Rodd, USNR.

Aircraft radio equipment developed during the war was installed in these planes. The main transmitter was the 500-watt SE 1310, mounted on the outside of the hull. The auxiliary was the 50-watt CG 1104, fitted within the hull. The receiver was the SE 950, modified by removal of the radio direction-finder elements and the two stages of audiofrequency amplification. Radio direction-finder equipment consisted of the standard revolving coils installed in the afterpart of the hull and a control board. The six-stage audio radiofrequency amplifier SE 1605B was provided for signal amplification for both traffic and direction finding.. Skid-fin and trailing-wire antennas were installed for both transmission and reception.[46]

Considerable difficulty was experienced in installing the equipment because it could not be placed in the planes until all other apparatus had been installed and tested. The only place the direction-finder coils could be installed was in the after compartment, where it was surrounded by lighting cables, the brace wires of the hull, and the control wires to the tail. These tended to act as a shield and a refractor and also radiated the ignition disturbances, thereby

[44] Johnson, op. cit., pp. 129–135.

[45] Hooper, op. cit., recording 24R60.

[46] "History of the Bureau of Engineering, Navy Department, During the World War," op. cit., p. 124.

decreasing the signal-to-noise ratio. During preliminary tests the direction finder in the NC–2 gave accurate bearings up to distances of 50 miles. Just prior to the beginning of the flight, changes to the auxiliary ignition systems reduced this range to 15 miles. Immediately after this, the planes were tested for full load conditions and thereafter there were no opportunities to flight-test the radio equipment or to calibrate the direction-finder equipment.[47]

On the first leg of the flight, Rockaway Beach to Halifax, the NC–3 had a forced landing 40 miles short of its destination. Using the auxiliary transmitter, communication was established with the tender U.S.S. *Baltimore* within 50 seconds. Information giving the location of the plane, the trouble encountered and that no assistance was required was transmitted.[48]

It is possible that time would have been made available for the proper readying of the radio equipment had this first crossing of the Atlantic by aircraft not developed into a race between the United States and England. Three teams of British aviators were already at St. Johns, Newfoundland, preparing for transatlantic flights.[49]

A statement made by Reed at this time gives an insight as to the general view of the enterprise:

> If the flight were successful, not only would an immense amount of valuable . . . information be obtained concerning long-distance overseas flying, but Naval Aviation, the Navy Department, and the whole country would receive the plaudits of the entire world for accomplishing a notable feat in the progress of science; the mass of the people would be made to realize the importance of aviation as a valuable arm of the naval service and the way would be blazed for others to follow and thus act to promote commercial trans-Atlantic service.[50]

At Trepassey Bay, Newfoundland, the end of the second leg, weather conditions prevented departure of the American planes for the Azores. Load conditions for this, the longest leg, prompted Towers to order the removal of the auxiliary transmitter to reduce the weight by 26 pounds.

To provide rescue and navigational assistance, 68 destroyers were stationed, at intervals of 50 miles, along the route from Newfoundland to the Azores and then on to Lisbon. These were augmented at 400-mile intervals by five battleships which functioned as weather stations. Since the greater part of the leg between Trepassey Bay and the Azores was flown during darkness, the picture presented must have been one of a gigantic traveling Fourth-of-July celebration. The searchlights of the ships were directed skyward as the planes approached. As they passed over each station the ships fired star shells until each plane acknowledged by radio.

Communications with the planes in flight were excellent. They were heard by the radio station at Bar Harbor, Maine, when 1,450 miles distant. Communications were maintained between the planes and shore for 700 miles and between planes and destroyers for 500 miles. Signals emanating from the U.S.S. *George Washington,* distant 1,800 miles, were copied by one of the planes. The radio direction finder was used constantly for homing on each succeeding station vessel.[51]

Dense fog was encountered as the planes approached the Azores. The NC–1 was forced down about 100 miles from Flores, but was promptly contacted by the station vessel which unsuccessfully attempted to tow her to port. Forty-five miles from the same port, the flagship NC–3 was forced to land in rough water prior to transmitting her position to the station vessels. Since the auxiliary transmitters had been removed, there was no transmitting equipment which

[47] U.S. Naval Institute Proceedings, vol. VIII, 1920, R. A. Lavender, "Radio Equipment on NC Seaplanes," p. 1604.

[48] Ibid., p. 1607.

[49] It was not until 14 June, a fortnight after the NC–4 arrived at Plymouth, England, that Alcock and Brown completed their nonstop flight from Newfoundland to England.

[50] Archibald D. Turnbull & Clifford Lord. "History of United States Naval Aviation" (Yale University Press, New Haven, Conn., 1949) p. 166.

[51] "History of the Bureau of Engineering, Navy Department, During the World War," op. cit., p. 124; Lavender, op. cit., p. 1605.

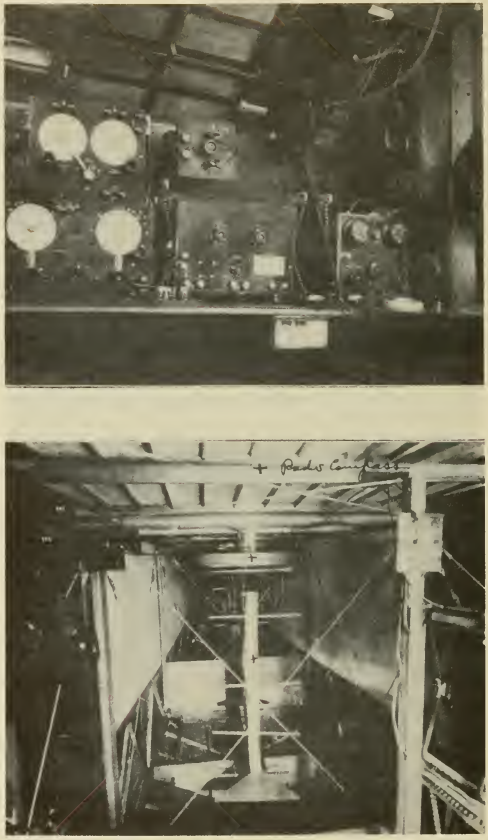

FIGURE 23–4. Radio installation in NC planes.

could be used because the motors could not be run without danger of damaging the plane's hull. The plans for search could be heard on the plane's receiver. Ultimately, the NC–3 managed to drift and sail into Ponta Delgada Harbor. Luckily, the NC–4 spotted a hole in the fog and landed at Horta at 0925, 17 May.

The NC–3 was severely damaged and could not proceed. On 20 May the NC–4 joined Towers at Ponta Delgada. From there it departed for Lisbon, Portugal, at 1818, 26 May. Shortly after departure the auxiliary ignition system became defective and was cut out. The radio direction finder again had an operable range of at least 50 miles. At the same time a casualty affected her magnetic compass and caused her to drift 40 miles from her prescribed tracks. Utilizing the transmissions of the closet station vessel, which was determinedly transmitting in an endeavor to gain contact, the plane was homed to the proper location and proceeded to Lisbon, homing thereafter on each successive vessel. She landed at 1602, 27 May, and later proceeded to Plymouth, England.[52]

The intense interest in this flight and the acknowledged role played in its successful conclusion did much to convince aviators of the necessity for aircraft communications and navigational aids. This interest has continued through the years until today the navigation of planes is almost totally electronic.

[52] Ibid., p. 151.

EPILOG

Considering, under normal conditions, 5 years as the accepted period of time between the conception of an idea and the operational use of new equipment, one cannot help but be amazed at the miraculous developments of a short period of months. Both the Western Electric Co. and the General Electric Co. were engaged in research in radio equipment for England and France prior to our entrance into the war. When we became a combatant this research, intensified by the patriotism of the management and workers, produced results of which all Americans should be proud. The work of the naval radio engineers and their accomplishments cannot be overly praised. In commenting upon the presentation of the paper "Naval Aircraft Radio" by T. Johnson, Jr., before the Institute of Radio Engineers, New York, on 4 June 1919, Mr. John V. L. Hogan, then president of that noted body, stated:

> I wish particularly to express my appreciation of the assistance which the Aircraft Radio Division of the Bureau of Steam Engineering . . . . has given toward the advance in radio for aeronautic use. From details of design, apparently minor in importance but so often of tremendous consequence in service, right through to such basic topics as the effective capacity, inductance and resistance of flying antennas, Mr. Johnson has led us in a most helpful and constructive way. The success of commercial aircraft will depend largely upon the success of aircraft radio, and so large a contribution to progress as has been given to us by Mr. Johnson deserves the fullest measure of recognition.

CHAPTER XXIV

Procurement and Installation of Radio Equipment During World War I

STANDARDIZATION

Prior to the adoptance of the type number system,[1] radio equipment had been modified by the whims of individuals and installations had been made on ships without thought of standardized plans. When operating and maintenance personnel were transferred from one ship to another it was necessary for them to familiarize themselves with completely different installations.

Prior to 1917 the Radio Division had developed standard radio equipments for the various types of naval vessels. These had been assigned SE type numbers for convenience in assembling the various components required for a complete installation.[2] In fitting a ship with radio equipment it was only necessary to provide the type number of the several complete assemblies, such as antennas, transmitters and receivers, comprising the complete installation. No modifications to equipments were permitted except by a change order issued by the Bureau. This was the beginning of a complete standardization which would eventually cover the elements of each individual component and tremendously decrease the number of spare parts required to be carried in stock. For many years progress toward this goal would be slow because of the constant improvements in newly purchased radio equipment combined with the economic necessity of retaining older equipments despite the availability of more modern types.

Following the standardization of equipments, standard installation plans were drawn up for each type and class of vessel. There were necessarily numerous modifications of these standard plans due to the variations in individual ship construction. These modifications required Bureau approval, thereby limiting them to those absolutely essential. Later, as the construction of the various types of ships became more nearly uniform, these modifications were materially decreased, especially in the smaller vessels. All ships under construction at this time and thereafter had specially designed radio spaces. Whenever possible, separate receiver and transmitter spaces were provided, with the latter usually being below the main deck. However, material improvements resulted in numerous departures from the standard installations.

PROCUREMENT OF MATERIAL

The mobilization requirements for military radio equipment were enormous. The Army required field sets to equip a planned force of approximately 2 million men. The Navy requirements for fitting new construction and augmenting the communication facilities of existent ship and shore

[1] Supra, ch. XVII.

[2] Because of the confusion that resulted from the assignment of type numbers to components and to assemblies of components, a model designation was later assigned a complete equipment.

stations amounted to a staggering total of over 10,000 sets. To avoid competing for manufacturing facilities, Gen. George O. Squier, Chief Signal Officer, USA, and Hooper established procurement procedures wherein each service had priority in contracting with specified companies. The Army with its large requirement for field apparatus and voice communications controlled the output of the Western and General Electric Cos., while the Navy controlled the output of the numerous small radio manufacturing companies.[3] These procedures prevented the skyrocketing of prices and the assignment of contracts to companies for equipment in excess of their production capabilities.

The Radio Division determined its requirements and made allocations to the various companies in accordance with their manufacturing capabilities and experience in order that each would manufacture the type of equipment for which it was best fitted and tooled. In general, this list was made up to provide two or more sources of supply for each item. This necessitated abandonment of established competitive bidding procedures. The first list of allocated equipment was taken by Hooper to the Contract Division, Bureau of Supplies and Accounts, with a request that the Bureau of Engineering be given a free hand in ordering the material. The Chief of the Bureau of Supplies and Accounts, doubting his authority to depart from established procedure, took the list, the request, and Hooper, to Assistant Secretary of the Navy Roosevelt who quickly approved and endorsed with the initials, "FDR." [4]

Hooper's next step was to give the manufacturers 2 days in which to submit prices for the items allocated them. When these were submitted, at reasonable costs, the companies were awarded contracts. In cases where there was evidence of attempts to profiteer, companies were directed to manufacture the equipment on a cost-plus-10-percent basis. To cover the cost of expansion of its Aldene, N.J., plant the American Marconi Co. was allowed an additional 10 percent.[5]

Immediately upon the issuance of the contracts and orders, there was a hurried effort on the part of several companies to procure radio engineering talent. This could have resulted in some companies losing the people necessary for the satisfactory completion of their orders. The Bureau immediately countered this by informing the proselyting firms that their actions were not in the best interests of the Government and that further effort in that direction would result in cancellation of their contracts.[6]

There were some items for which a second source of supply was nonexistent. In these cases the supplying companies were directed to provide a second firm with the necessary information to enable it to produce the item. A few companies demurred but the mere suggestion that the Government would take over and operate their plant provided sufficient incentive to evoke compliance.[7]

Quickly, a steady and sufficient supply of standard equipment, manufactured under Navy specifications and in many cases from Navy supplied plans, became available. During the entire period of the war, not one ship was delayed in being put into operation by the lack of radio equipment.[8]

[3] Clark in his unpublished manuscript, "Radio in War and Peace," p. 319, infers that the two companies controlled by the Army performed no work for the Navy. This is incorrect. The contractural records of the Navy and lists of radio material provided by them during and after the war show that they manufactured thousands of radio components. Likewise, the National Electric Supply Co., a Navy controlled firm, produced thousands of sets for the Army.

[4] "Radioana." Massachusetts Institute of Technology, Cambridge, Mass., G. H. Clark, "Radio in War and Peace," p. 321–323.

[5] Ibid.

[6] Ibid.

[7] Ibid.

[8] "History of the Bureau of Engineering, Navy Department, During the World War," Washington, Government Printing Office, 1922, p. 91.

PROCUREMENT AND MAINTENANCE OF THE EMERGENCY FLEET RADIO INSTALLATIONS

In late August 1916 Congress passed the Ship Purchase Act, creating the U.S. Shipping Board which was given authority to build, purchase, or lease vessels "suitable for use as naval auxiliaries" and to operate them for a period not to exceed 5 years following the termination of the war. By late 1917, ships constructed under this act were nearing completion.

Hooper convinced the Shipping Board authorities that they should request the Navy Department to procure, maintain, and operate the radio equipment on their newly constructed vessels. This was done ostensibly to prevent the Shipping Board requirements for this equipment from interfering with other military procurement. Actually, the motive was to weaken the communication position of the British-dominated American Marconi Co., thereby strengthening Daniel's position in seeking a Government radio monopoly. The Secretary, an announced proponent of Government ownership of all radio facilities, approved Hooper's action and the Shipping Board request.[9]

The Bureau increased the existing contracts by the amounts necessary to provide the equipments for the newly constructed Shipping Board vessels. These were installed in specially provided spaces by the builders under the supervision of the radio engineers of the nearest navy yards. In wartime these ships sailed in convoys under escort protection and did not require long-range transmitters. Their operators were relatively inexperienced necessitating the use of the least complicated equipment. The standard installation, which met the requirements of Public Law 238, 13 August 1912, consisted of 2-kw. quenched-spark transmitters and a crystal detector-receiver with the necessary ancillary equipment. Maintenance was provided by the various navy yards and overseas naval bases.[10]

After our declaration of war, the Shipping Board made plans to commandeer all vessels under U.S. registry in excess of 2,500 tons displacement. This was done on 1 November 1918 by transferring registry to the Government and then turning the ships back to their previous owners to be operated by them for the Government. Hooper's next action was an endeavor to convince the Shipping Board authorities of the desirability of purchasing the leased radio equipment of these vessels and having it maintained and operated by the Navy. Before final decision was made, Hooper was ordered to sea in command of the U.S.S. *Fairfax* and was relieved by LeClair.

LeClair, busy with wartime administrative duties, the responsibility for augmenting transatlantic communications, bolstering the aircraft radio equipment program, and improving shipboard apparatus, did not concern himself with the communications political situation. However, during his year in this office, he did arrange for the purchase of the patents and shore stations of the Federal Telegraph Co. in order to block the purported effort of British Marconi to obtain control of the arc patents.[11] LeClair's action was based upon the

[9] "Radioana," op. cit., Clark, "Radio in War and Peace, p. 326. Clark claims that the protection of the contracts was the primary reason for Hooper's action but that the desire to break the Marconi monopoly was more deeply seated in his mind.

[10] Ibid.

[11] Gleason L. Archer, "History of Radio to 1926," (American Book-Stratford Press, Inc., New York, 1938), p. 137 states:

"Early in the summer of 1917 there were rumors that the Federal Telegraph Company was in negotiation with the Marconi Company in regard to a consolidation whereby the latter would take over the patents and physical assets of the Federal Company. Whether these rumors were fed to the Navy Department as a means of stimulating a hoped—for sale to the Government is by no means clear. The probabilities are that there was a basis of fact for the report. Subsequent disclosure, however, indicates the sale to the United States Government was engineered under suspicious circumstances. A scandal of major importance was averted by the suicide of one of the chief actors in the transaction and the resignation of suspected officials."

necessity of protecting the continued use of this type of transmitter. The Secretary's approval of the purchase was readily obtained since the sole ownership of the American rights to the Poulsen patents would increase his chances of establishing a Government radio monopoly.

Hooper returned in August 1918 and relieved LeClair. One of his first acts was to renew his efforts to convince the Shipping Board officials that they should purchase the leased installations. Shortly thereafter the Navy Department was instructed to purchase the installations of 267 vessels against the Shipping Board account. Similar action was taken by the Railroad Administration which was operating 63 ships with leased installations.

American Marconi interests were unwilling to sell their ship stations unless their coastal stations were also purchased. This was acquiesced to and readily approved by the Secretary. The transaction was consummated on 30 November 1918, 19 days after the signing of the Armistice. For the time being, the Government owned most of and operated all radio stations in the United States and on vessels registered thereunder. Upon the termination of the President's wartime powers there would be few stations to be returned to commercial interests.[12]

FITTING AND MAINTENANCE OF NAVAL VESSELS

The rapid expansion of personnel and the limited training which could be given them in technical fields, especially in the recently developed electronic circuits, made it necessary to expand the radio facilities of the navy yards and to establish additional ones at all oversea bases.

Equipment was fitted in the newly constructed ships at the navy yards after delivery by the builders. The installation of additional sets, and repairs and modifications to or replacement of existing ones in the older vessels were accomplished either at the yards or oversea bases. Radio direction finders required calibration after installation. Whenever circumstances allowed, this was done while ships were at the yard by special teams, based at the Boston Navy Yard, travelling the entire east coast to accomplish their work. In many instances it was necessary to install this equipment overseas after which it was calibrated by personnel of one of the several naval bases.

Radio repair facilities were established in 1917 at naval bases in Queenstown, Ireland; Gibraltar; and at Brest, Lorient, and St. Nazaire, France. Additional bases in France were established during 1918 at Rochefort, La Pallice, Gironde River, Le Havre, and Marseille.[13]

PROBLEMS WHICH AROSE FROM COMBINED NAVAL OPERATIONS

In June 1917 six of our battleships, under the command of Rear Adm. Hugh Rodman, USN, joined the British Grand Fleet as the 6th Battle Squadron. The remaining capital ships were retained within the protected waters of the Chesapeake Bay as an augmenting force in the event the German Fleet escaped from Wilhelmshaven, where it was being contained by the combined fleet. It immediately became evident that the radio installations of the two navies were incompatible. British men-of-war had been designed and fitted primarily to operate in close formation in the restricted waters to the north and east of the British Isles. Their radio equipment was highly selective and insensitive. The U.S. Navy had been designed and fitted to fulfill its mission which, as the country's first line of defense, was to meet and defeat an

[12] Infra., ch. XXX.

[13] "History of the Bureau of Engineering, Navy Department, During the World War," op. cit., p. 125.

enemy on the high seas, distant from our shores. This mission necessitated the scouting of immense sea areas by ships widely separated on a scouting line. Our radio requirements were diametrically opposite those of the British. This posed quite a problem. No one could foretell the duration of the war nor whether the Germans could continue their advance and possibly force the Allies to fall back and fight the war from American shores. The radio equipment installed in any of our scouting ships could not be supplanted by short-range apparatus.

In accomplishing maximum selectivity in receiving, the British utilized an acceptor-rejector[14] circuit consisting of special coils and condensers so placed in the antenna circuit that two signals of different frequencies might be received on one antenna without mutual interference or loss of energy. Nodal points[15] were artificially produced in the antenna by circuit arrangements and from these very low impedance shunts were tapped off and used to eliminate, soundlessly, all signals except those on the exact desired frequency. The device for producing a nodal point in the antenna circuit was a series coil and condenser which formed the acceptor circuit. The shunt trap or rejector circuit consisted of a number of fixed condensers and a single-turn variable loop. The numerous adjustments required, the exactness with which each had to be made, and the necessity for positive contact resistance, made the successful use of this device extremely difficult. In addition to this, all parts of British receiving equipment were carefully screened to eliminate electrically generated noises and their receivers were placed in soundproofed, screened and grounded booths. Their transmitting keys were enclosed by heavy brass containers grounded to prevent their acting as miniature transmitters.[16] They continued to use the inefficient open spark gap transmitters which created much more local interference than the U.S. Navy quenched gaps. For short-range communications they replaced the spark gaps of their transmitters with motor buzzer sets.[17] They also used a 2-kw. arc which was small and dainty but highly efficient in comparison with ours. Their transmitters were normally located below decks with the antenna leads brought up through screened trunks. Break keys were standard equipment.[18] Whereas we had continued to use frequencies below 1,500 kc. they utilized one of about 2,380 kc. for intrafleet communications.[19]

The immediate problem was solved by replacing the radio equipment of the ships of the 6th Battle Squadron with British-type apparatus. A similar system was designed by our radio engineers and installed in the remaining battleships.[20] This consisted of Models E, F, and "R" receiving equipments. The British acceptor-rejector circuit was adopted as a component of these equipments. The Model E system consisted of one low and one medium frequency receiver so arranged that either or both could be used simultaneously on one antenna. The Model R system consisted of a single medium frequency receiver. The Model F system was the same as the Model R except that it was provided with additional features permitting its use for double reception by utilizing one of the receivers of the Model E system. The transmitters were not relocated below decks and no changes were made to them except the adoption of the British motor buzzer sets as a substitute for the spark gap for low-powered purposes. Although these installa-

[14] The acceptor-rejector circuit is described briefly in Appendix M.

[15] A nodal point exists wherever the potential in a circuit with respect to ground is zero.

[16] "Radioana," op. cit., Clark, "Radio in War and Peace," pp. 340–345.

[17] The motor-buzzer set is described briefly in Appendix M.

[18] "Radioana," op. cit., Clark, "Radio in War and Peace," pp. 340–345.

[19] Ibid.

[20] Annual Report of the Secretary of the Navy, 1918 (Washington, Government Printing Office, 1918), p. 28.

tions were not as complete or as good as the British installations they did provide improvement for tactical uses.[21]

[21] United States Navy "Manual of Engineering Instructions" (Washington, Government Printing Office, 1921), p. 31–148.

We learned much from the British and adopted many of their manners of usage such as the broadcast method of delivering orders and information to the fleet, the necessity of maintaining radio silence until enemy contact was established, and the need of strict radio discipline.

CHAPTER XXV

Operation of the World's Largest Radio System

MOBILIZATION

The President's signature to the resolution declaring war was the signal to place in effect previously prepared war plans. Executive orders based upon the wartime powers of the Commander in Chief had been prepared and only awaited his signature for enactment. Most of these were signed on 6 April and placed into effect the following day.

The mobilization of naval communications, under the guidance of Bullard, had commenced sometime earlier with the voluntary acceptance of active duty by hundreds of reserves. The increased volume of radio traffic which resulted from the imminence of war necessitated the augmentation of facilities and the use of this previously trained group.

With the country at war, the remainder of the Communications Reserve was immediately called to active duty. They were augmented by the almost immediate enrollment of hundreds of commercial and amateur operators who had not previously joined but who now saw it as a patriotic duty. The closing of the commercial stations made additional hundreds of operators available for duty. The immediate requirements for trained operators were well met by these people. However, as the war progressed, more and more ships were built and commissioned, causing a constantly increasing demand for qualified radio operators and other communication personnel.

TRAINING OF WARTIME PERSONNEL

The electronic communication equipment of today is able to perform many mechanical brain functions, with its flashing red lights and ringing bells indicating electrical or mechanical difficulties or the rejection of some message because of a humanly generated error in routing instructions beyond its digestive capability. As advanced as this is, it is only as efficient as the personnel who operate it. In World War 1 all these functions had to be performed by additional thousands of men who required training to provide the communications necessary for the prosecution of the war.

To meet these requirements, radio schools were established in each naval district to provide preliminary training in radiotelegraphy and to eliminate those who lacked the essential aptitude. To provide advanced training two schools were established, one on each coast. Following the close of the college year of 1917, Harvard University offered buildings for classrooms, laboratories, and dormitories. This offer was gratefully accepted, the school was established and grew rapidly into an institution of mammoth size. A similar, but smaller one was established at Mare Island, Calif. By the end of 1917 almost 5,000 students were attending the 4-month intensive radio operating and indoctrination courses and were being graduated into service at a rate in excess of 100 a week. By early 1918 this was increased fourfold.[1]

[1] Wireless Age, October 1918, p. 42.

Amateur experimenters proved the best students since they already possessed an ability in manipulation gained by their previous activity.[2] However, many young men who had never before seen radio equipment were proficiently trained. Many of these later became actively engaged in the ever-expanding field of electronics.

OPERATION OF THE SHORE RADIO SYSTEM

The major problem of the Naval Communication System during the war was that of augmenting transoceanic communications facilities. The System was augmented by the commercial facilities taken over upon our entrance into the war.

With the new San Diego station in operation, and the Pearl Harbor and Cavite ones completed shortly after our entrance into the war, augmented by commercial circuits, the communication problem in the Pacific was relatively minor.

With no farflung possessions in the Atlantic to protect, nor on which to erect a high-power station, improvements in communications had been limited to providing a reliable circuit between the Canal Zone and Washington and increasing the range of radio communication between the seat of government and the commanders of forces operating in the North Atlantic. Considerable transatlantic operating experience had been gained in operating the foreign-owned stations during the neutrality period and there were some improvements in equipment, which had increased reliability. Despite this, in 1917 not one transatlantic circuit was capable of providing continuous service. Main reliance for communications between the United States and her European Allies continued to be placed upon the cables. To improve conditions on the transatlantic circuits, both reception and transmission were accomplished at locations remote from Washington. Traffic between these points and the Navy Department was manually relayed over landlines. During the early months of the war, transatlantic signals were received primarily at Sayville, backed up by Tuckerton. Landlines connected the two stations in order that Sayville might operate the Tuckerton transmitters and for forwarding Tuckerton copy to Sayville for comparative and fill-in purposes.[3]

The summer of 1917 demonstrated that receiving in this manner was entirely unsatisfactory. The successful development at Great Lakes of the submarine and subterranean collector systems for reception induced the Bureau to install such a system at the Belmar, N.J., Marconi station which had been taken over but not used at the beginning of the war. Taylor, who had conducted the Great Lakes experiment, was ordered in command with the title of Transatlantic Communications Officer. He was dually responsible to the Director of Naval Communications and to the Chief of the Bureau of Steam Engineering. By the end of October 1917, Belmar was in operation and became the control center for transatlantic communications. Early in November it was decided to utilize the Marconi receiving station at Chatham, Mass., as a backup for Belmar. The two stations were connected by landline for relaying Chatham's copy. It was soon discovered that Chatham was of no assistance to Belmar and it was closed in October 1918.[4]

Mr. Alessandro Fabbri who owned an amateur radio station at Otter Cliffs, Maine, had been commissioned an ensign in the Naval Reserve Force. Early in 1917 the remarkable transatlantic reception capabilities of this location came to the attention of the Navy Department. Fabbri offered to rent this station to the Government for $1 a year. On 28 August 1917, this offer was accepted and it became part

[2] Ibid., January 1918, p. 707.

[3] "History of the Bureau of Engineering, Navy Department, During World War I," Washington, Government Printing Office, 1922, p. 104.

[4] Ibid., pp. 104–105.

of the Naval Communications System. Fabbri was ordered in command of the station. Early in 1918 this station, which had first been used as a coastal one, was removed from the organization of the 1st Naval District and placed under the command of the Transatlantic Communication Officer to whom Fabbri then reported for duty. By midsummer of that year complete reception of all frequencies used on transatlantic circuits at Otter Cliffs was definitely assured. At that time the received signals were patched straight through to and copied at the Navy Department Communication Center. At the same time control of all transatlantic transmitters was taken over by that center.[5]

The Arlington transmitter was principally used for broadcasts of traffic to the fleet. When not required for transatlantic work, Tuckerton assisted in this. Certain Atlantic and gulf coast stations were designated to provide ship-shore communications which were handled in code under strict censorship.[6]

FLEET COMMUNICATIONS

At the time we entered the war the German Fleet was being contained at Wilhelmshaven in the Jade, and had not ventured forth since the Battle of Jutland, 31 May-1 June 1916. Later, on 23-24 April 1918, one abortive attempt was made to attack British convoys off the Norwegian coast. This operation was discontinued because of a breakdown of the *Moltke* without the Allies realizing that they had been at sea until the *Moltke* was discovered and torpedoed 10 miles north of Heligoland.

The only major U.S. Navy units taking part in operations with the combined fleet were the battleships which constituted the 6th Battle Squadron. These ships conformed to British practices and, as previously related, were refitted with British radio equipment. The remainder of the large men-of-war were normally kept in the Chesapeake Bay as a reserve force in the event the German Fleet managed to escape to the high seas.

U.S. destroyers, acting as convoy escorts, minelayers, and as hunter-killer groups for detecting and destroying submarines, and small submarine chasers also performing the latter duty bore the brunt of our wartime naval operations. When these units used radio at sea they normally used the CW 936 short range voice transceiver. Orders and instructions were broadcast them on regular schedules. Intracommunications within the tight convoy formations were readily handled by visual methods.

From its own success in keeping track of the enemy, the Admiralty realized the necessity of ships at sea maintaining radio silence. In order to deliver orders and intelligence to them they evolved the "broadcast method" wherein the ships copied definite schedules on which messages were transmitted with concealed headings. Upon our entry into the war we quickly adopted this system. Messages to ships in port and normally to those at anchor in the Chesapeake were transmitted by wirelines and relayed by visual means.

A "force tune system," now known as "fleet frequency plan," which had been started in a small way by Hooper when he was fleet radio officer, was adopted. This was necessary because of the extremely limited radio equipment fitted into most vessels and also to reduce the number of transmissions on a single frequency. In this system each force or unit acting independently was assigned its own frequency. Intercommunication between various forces was through the force commander and thence to the fleet commander for relay to the commander of the force in which the addressed unit was a part. Force and fleet flagships usually had additional equipment because of the need of the force commander to communicate with the higher echelon of command as well as

[5] Ibid., p. 106.

[6] Ibid., p. 94.

with his own ships. The fleet and force commanders usually guarded the broadcasts for their ships, relaying the messages by visual methods.

To regulate the delivery of emergency and important traffic three priority classes of messages were established. The "Rush" classification for messages to ships was restricted to the use of the Secretary of the Navy, the Chief of Naval Operations, commanders in chief of fleets, and such other officials as might be designated from time to time by the Director of Naval Communications. Such messages were transmitted immediately by the direct method and their receipt was acknowledged by the recipients.[7] For ships at sea, emergency messages or enemy contact reports were preceded by an emergency signal, which required the observance of radio silence until delivery to addresses was effected. The contact reports were encoded in a well-recognizable system. "Routine" dispatches required less immediate handling than "rush" ones but could not be held for transmission over 2 hours. "Nite" was assigned as the precedence for messages which could await delivery to the addressee by 0800 of the following day.[8]

COMMUNICATIONS SECURITY[9]

Credit for the complete awakening of the security consciousness of U.S. naval officials is due the British Admiralty. Upon our entry into the war they advised the Navy Department of the successes of the German Communications Intelligence Organization and of the inadequacy of our systems. At this time the British were far ahead of us in the use of secure ciphers. This can be attributed to their earlier adoption of radio for tactical communications and to their proximity to other countries which made interception of their messages easier. When our battleships joined the Grand Fleet in 1917, it was necessary that "joint Allied security publications" be utilized. Since these were based primarily upon the British systems, we immediately acquired the benefit of their experience gained during 3 years of conflict.

One of the earliest available records is "Code and Signal Memorandum CSM No. 1 (CSP 103)" which was a confidential, nonregistered memorandum issued under date of 10 October 1917. Since it describes the situation which existed during the first year of our participation in the war, the following excerpt is quoted:

> Under present conditions there has been a large increase in the number of signal books, codes, ciphers, radio regulations, radio and visual calls, etc., issued to the service, and, due to lack of published instructions on the subject, some uncertainty and confusion as to the issue and use of publications of this kind has resulted. This memorandum is issued with a view to furnishing in compact form information on this subject, to increasing the efficiency of confidential communications, and to simplifying the question of handling this matter on board ship, at naval stations, and in the department. Additional memoranda will be issued from time to time in order to bring up to date the information contained herein.

The organization for handling codes, ciphers, signals, etc. in the Department consisted of the Office of Naval Intelligence, the Director of Naval Communications, and the Code and Signal Section of the Division of Operations. However, the above mentioned memorandum stated, ". . . It is planned eventually to assign the Code and Signal Section to the Office of the Director of Naval Communications when office facilities become available."

It also listed the following U.S. Navy

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[7] "Communications Regulations of the United States Navy, 1918," Press, U.S. Navy Recruiting Bureau, New York.

[8] This restriction upon the assignment of priority classification to nontactical messages would have been beneficial in World War II, when practically unlimited authority was granted originators to assign classifications. This frequently resulted in slowing the delivery of very important traffic.

[9] This material was provided through the courtesy of Rear Adm. H. C. Bruton, USN, while Director of Naval Communications. It was assembled, at his direction, by the Registered Publication Section and forwarded by letter dated 30 Dec. 1957.

publications as having been distributed by the Code and Signal Section:

General Signal Book, 1913
Battle Signal Book, 1913
Service Radio Code, 1914
Naval Cipher Box and Ciphers
Secret Fleet Ciphers
S. C. Ciphers (SigCode Ciphers) (Now being prepared to supersede "Secret Fleet Ciphers")
D. P. Ciphers (District Patrol Ciphers)
M. S. Ciphers (Merchant Ship Ciphers)
U. S. Recognition Signals (Now in preparation)
War Instructions for United States Merchant Vessels
Visual Calls Memoranda
Radio Calls (except commercial calls)
Signal Letters of U. S. and Foreign Government Vessels (Four-letter visual calls)
Code and Signal Memoranda
Record Book for Signal Books, Codes, Ciphers, etc.

The following supersession data was included:

. . . The old Navy Secret Code (1887) and the Navy Secret Code (1908) are considered as having been compromised. The former is practically obsolete; the latter can be relied upon for secrecy only when blinded and hereafter will be issued only in special cases. The following pubications are no longer issued or recorded:

Larrabee's Cipher Code
Useful Curves, Scouting and Torpedo Danger Area
Naval Militia Tactical Signal Book
Radio Signals, 1913
Western Union Code.

CSM No. 1 further stated that the Code and Signal Section handled and distributed all Allied publications furnished the Department by Allied Governments for use, and listed the following issuing offices:

District Communication Superintendent at: Navy Yard, Boston; Navy Yard, New York; Navy Yard, Philadelphia
Aide to the Commandant, Navy Yard, Norfolk

The "Naval Cipher Box (NCB)" and ciphers mentioned above had been developed by Lt. Comdr. Russell Wilson, USN, and were issued to the service by a letter of promulgation, dated 12 June 1917. The adoption of this system marked the beginning of a real security consciousness on the part of naval officials. Prior to this codes A, B, C, D, and E, with provisions for encipherment by simple substitution or transposition, were considered adequate. The promulgating authority had no intention of endangering the new system by using it in conjunction with the old codes. Its use was restricted temporarily to one newly issued secret code until new codes A-1 through E-1 could be issued. In a little over a year, further improvements were incorporated and "Naval Cipher Box, Mark II (NCB Mark II)" was issued with instructions for safeguarding its use. Concurrent issues of codes A-2 through E-2 were made for use with the revised box.

Additional steps were taken at this time to increase the difficulties of cryptanalytical attack. Holders were divided into several classes based upon the echelon of command and to some extent the geographical area of operations. Higher echelons were holders of several classes, the lowest one held but one. Each class utilized a different cipher, with its own varying key changes based upon the amount of usage. The class issued the greater number of holders was used to a greater extent than those with limited holders and consequently was changed more often.

"Code and Signal Memorandum No. 1 (CSM No. 1)" was superseded by No. 2 (CSM No. 2) on 1 December 1917. This memorandum confirmed the assignment of the Code and Signal Section as a branch of the Naval Communication System. It also established the assignment of "Code and Signal Publication (CSP)" numbers to all U.S. publications (except NCB ciphers) issued by the Code and Signal section.

CSM No. 3 (CSP 130), dated 19 December 1917, did not supersede CSM No. 2. Based largely on information provided by the British Admiralty, it contained information on methods of cryptanalytic attack. The importance of observing established communication security rules was emphasized and the damages which could result from enemy cryptanalysis and traffic analysis were depicted.

During the war the Allied navies enjoyed a more wholesome cooperation and exchange of security information than did the ground forces. With the cooperation of the Admiralty the Navy endeavored to refine their cipher systems. The Army concentrated its efforts on the development of codes which when used to handle large volumes of traffic, inevitably become quickly compromised. Considerable success was attained in improving our ciphers and making them more difficult of attack. Originators of messages and communication personnel became more adept in avoiding errors and improper usages. Notwithstanding the above, compromises occurred and at times information was obtained by the enemy by successful cryptanalytic attack of our ciphers.

SHIPS MOVEMENT INFORMATION

Prior to our becoming a belligerent, the newspapers published daily reports of ship arrivals and departures. This was of great value to commercial interests and to the Government in controlling and protecting shipping in the harbors and off the coasts. To deny the enemy this information it was necessary to cease publishing it. New York, the largest port, suffered the most from this and it was found necessary to establish a Bureau of Shipping Information under the District Communication Officer. Later this was expanded to cover all the Atlantic and gulf ports.

On 10 January 1918, the Navy Department assumed responsibility for secure reporting of the movements of ships in United States ports to the U.S. Shipping Board. Prior to this time such reports had been received through the different collectors of the customs in plain language. This duty was delegated to the Director of Naval Communications. The existent organization, centered at New York, was expanded and retitled the Navy Shipping Information Office. A daily "Shipping Bulletin" was issued to the Government offices concerned. Additional information was provided to the Naval Overseas Transportation Service and to the U.S. Shipping Board relative to the ships operating under their directions. Upon the conclusion of the war this service was moved to the Navy Department and was continued, insofar as naval and naval controlled vessels were concerned, under the Ship Movement Office, Office of the Chief of Naval Operations.

LANDLINES

By March 1917 increased continental communications necessitated leasing private telephone and telegraph facilities. A Landlines Division was established in the office of the Director of Naval Communications with responsibility for providing those facilities required to meet the demands of the service. By the end of the war there existed a comprehensive leased network of telephone and telegraph lines extending north to Portsmouth, N.H., west to San Francisco, and south to New Orleans, La. Within the various naval districts, secondary leased wirelines connected the district headquarters with its outlying activities.

To clarify the responsibility for the administration of telephone service on shore General Order 367 was issued on 14 February 1918. It stated in part:

> . . . The public works office will be responsible . . . for providing local telephone facilities within navy yards and stations, and for providing the line facilities for connecting these yards and stations with the nearest exchange of the commercial telephone companies.
>
> The communication service will be responsible for providing such toll-line facilities as are required and secured on a leased basis, outside navy yards and establishments. In addition, this service will be responsible for the operation of all telephone plants provided for the naval service, and the supervision of all personnel handling such operations.
>
> Where it is necessary for the Navy Department to construct and own its own telephone plant outside naval establishments, the public works office of the district or adjacent navy yard or station, will be responsible for such construction and later maintenance.

COAST GUARD COMMUNICATIONS

The U.S. Coast Guard was transferred from the Treasury to the Navy Department for the duration of the war. Its communication facilities were placed under the supervision of the Director of Naval Communications. A survey of the Coast Guard's coastal communication system and of the coastal requirements of naval communications was made. Many additional cables from the mainland to offshore lighthouses were laid and interconnections with headquarters were established. The existent Coast Guard system was improved and utilized for the operations control of coastal patrols.

COMMUNICATIONS FOR OTHER GOVERNMENT DEPARTMENTS

The Naval Communications System provided radio communication service for all departments of the Government. War Department messages to France concerning the oversea movements of troops and cargo were delivered to naval communications for encipherment and transmission by radio or cable. Similarly, the President, the State Department, and the President's personal representative, Colonel House, the Shipping Board, the Fuel Administration, the Food Administration, and the Post Office Department all utilized naval facilities for handling messages to and from Europe. The first three listed were assigned special naval ciphers.

Aware that the German Communication Intelligence Organization maintained an intercept watch on our transatlantic communications, American news, prepared under the direction of the Committee on Public Information, was transmitted to Europe every night for the use of our forces abroad and as propaganda. President Wilson's "Fourteen Points" pronouncement of 8 January 1918 and his subsequent elucidations of them, especially his speech on the following 17 September, which launched the fourth Liberty Loan drive, were broadcast addressed to and acknowledged by the German radio station at Nauen.

ARMISTICE NEGOTIATIONS

On 4 October 1918 the German Government approached President Wilson through the Swiss Government asking him to arrange an armistice. The President was not satisfied as to the sincerity of the German Government and made queries through the Swiss. These queries were answered in a note delivered to the Swiss minister in Berlin at 1200, 12 October, Berlin time. So desperate was the internal situation in Germany at this time that Prince Maximilian of Baden, who had been called to the chancellorship in an endeavor to appease the people, took unprecedented action. On the same date, at 1545, Berlin time, he directed the German station at Nauen, on which we maintained a constant intercept watch, to transmit to the United States, addressed to the Director of Naval Communications, the information that the President's queries had been answered at noon. This was followed with a verbatim repetition of the text of the reply which stated the German and Austro-Hungarian Government's readiness to comply with our terms.

POST ARMISTICE COMMUNICATIONS

Cessation of hostilities brought no reduction in the volume of traffic that the Naval Communication System was required to handle. In fact, rapid demobilization increased the difficulty of handling the large volume.[10]

At that time the Secretary of the Navy stated:

> Radio communication, essential in time of peace and absolutely vital in war, has never had its importance so signally demonstrated as in the past three years, if the enemy had succeeded in cutting

[10] The Annual Report of the Secretary of the Navy, 1919, Washington, Government Printing Office, 1919, pp. 95–96.

the cables, radio would have furnished our only immedite means of communicating with Europe. During the peace negotiations and the demobilization of our European forces, when the cables were over loaded, our trans-ocean system transmitted millions of words of official dispatches and press reports, rendering a service could not have been performed by any other means.

To direct movements of convoys and transmit information regarding the enemy and issue orders to naval vessels and merchant ships a comprehensive method of transmission from shore was organized, making it unnecessary, except in rare instances, for ships at sea to use the radio apparatus,[11] thus avoiding the possibility of revealing their location to enemy submarines. All U.S. merchant vessels were provided with navy operators, to the number of about 5000.

The naval shore radio system handled, during the period between 1 July 1918 and 30 June 1919, 1,189,120 dispatches containing text amounting to an approximate total of 71,347,860 groups.[12]

Commenting on the work of the system both during and after the war the Chief Signal Officer of the U.S. Army stated:

In its cooperation with the United States Army and with the Allies in this project the work performed by the United States Navy has been indispensible. It was executed with vigor and skill, and was successful.[13]

After the Armistice, the General Electric Co. was requested to continue the development of transatlantic radiotelephony in order that the President on his trips to France to attend the Peace Conference might maintain telephonic communication with his aides in Washington. During his first trip in the U.S.S. *George Washington,* in January 1919, telephonic messages were received by that ship during the entire crossing. The President returned during the last week of February and made a second crossing in early March. By that time sufficient progress had been made so that successful two-way communication was provided.

CABLE CENSORSHIP

On 28 April 1917 an Executive order made the Director of Naval Communications responsible for cable censorship with the title of Chief Cable Censor. Censorship stations were established at New York, Galveston, Key West, San Francisco, Honolulu, Guam, Panama, Guantanamo, Cape Haitian, Port Au Prince, San Domingo, St. Thomas, and St. Croix. All cable messages to and from the United States were censored except those to and from Europe which for a short time were censored by our Allies. On 26 July 1917 this task was also taken over by the Chief Cable Censor.[14]

[11] The word apparatus as used must be considered as transmitting apparatus.

[12] The Annual Report of the Secretary of the Navy, 1919, op. cit., pp. 95–96.

[13] Report of the Chief Signal Officer to the Secretary of War, Washington Government Printing Office, 1919, p. 137.

[14] The Annual Report of the Secretary of the Navy, 1917, Washington, Government Printing Office, 1917, pp. 444–448.

CHAPTER XXVI

Development of Underwater Sound and Detection Equipment

PREFACE

Most major wars have caused an acceleration in the development of weapons systems or devices. This was particularly true during the past two global conflicts. The increased mobility of man and the increasingly rapid dissemination of voluminous news reports resulted in public interest being centered on the development of many of these systems and devices. During the past World War, first it was radar, then rockets, followed by V-bombs and then, transcending all others, the atomic bomb. In World War I, the development of submarine tactics and the destruction of Allied merchant shipping by the Germans was of such a magnitude as to cause the gravest apprehension regarding our ability to provide the necessary logistic support to prosecute the war on the European Continent. All measures taken to combat this menace were followed by the public with intense interest but, since it was necessary to seek out the enemy submarines before they could be destroyed, none was followed with closer interest than was the development of means of detecting these destructive and elusive undersea vessels.

HISTORICAL BACKGROUND

The final successful development of underwater sound and detection devices was the result of two things: man's inquisitiveness concerning the unknown ocean depths; and his desire to provide a longer range method of communication while embarked upon water. The first realization that sound carried through water is lost in antiquity. Long ago the Ceylonese signaled each other while at sea by striking an earthen "chatty" which produced a sharply percussive sound that could be heard for several miles by an ear held against the bottom of a boat.[1] About the end of the 15th century, Leonardo da Vinci, a seminal engineer and physicist, as well as painter, anatomist, and inventor, noted that if one end of a tube was placed in water and the other to the ear, a person on a stationary vessel could hear the movements of other vessels in the immediate vicinity.[2] In 1826, Colladon and Sturm, in endeavoring to obtain the velocity of sound in water, used a hammer to strike a submerged bell. The sound waves emitted were received 10 miles away by an ordinary ear trumpet the mouth of which was covered by a diaphragm and held underwater.[3] Early in the 19th century the British scientist, Tyndall, was provided a liberal grant to investigate the reason why fog signals in the air could not always be heard or, when heard, could not be accurately located.[4] Later Henry, our noted scientist, was commissioned to conduct a similar study by the U.S. Government. Both arrived at the conclusion that fog signals in the air were untrustworthy.[5]

[1] H. J. Fay, "The Submarine Signal Company" (Soundings, publication of the Submarine Signal Co., Boston, Mass.), November 1944, p. 4.

[2] Thomas H. Whitcroff, "Sonic Soundings as Developed by the U.S. Navy" (U.S. Naval Institute Proceedings, 1943), p. 216.

[3] Fay, op. cit., p. 6.

[4] Ibid.

[5] Ibid.

Interest in what lay beneath the seas is as old as the memory of man. An Egyptian artist of the 12th dynasty, more than 2,000 years before the dawn of Christianity, left a graphic description of an early sounding lead. Later, Herodotus described sounding the Nile with a plummet. The Greek, Eratosthenes of Alexandria, who demonstrated that the earth was a sphere approximately 25,000 miles in circumference, indicated that he was aware of large variations in depth in the Mediterranean. Posidonius, his successor, charted the Sardinian Sea about 150 B.C. During the period between the decline of Greek culture and the end of the 15th century little concern is recorded of man's interest in the structure of the world or in oceanography, although there are numerous indications that the lead and line were used in the interests of safe navigation. The voyages of Columbus reawakened interest concerning the earth and its navigable waters. This interest finally culminated in Magellan's circumnavigation of it. The first recorded evidence of the dipsey lead (weighing between 30 and 100 pounds) is found in Capt. John Smith's "Seaman's Gram," published in 1627. Before the development of more practicable methods it was used for deep-sea soundings up to 100 fathoms. A lighter lead, weighing between 7 and 14 pounds, was, and occasionally still is, used for shallow-water soundings.[6]

About 1825, Jean Francois Arago, astronomer, engineer, and physicist, suggested that propagated sound waves could be utilized to measure ocean depths. This was attempted in 1854 by Lt. Matthew Fontaine Maury, USN. He exploded petards in deep ocean, hoping to receive the echo, but failed because he did not use a direct connection between the ear and the sea.[7]

Oceanography was brought into existence by Maury who, because of his work in this field, became known as the "Pathfinder of the Seas." In 1855, he wrote his "Physical Geography of the Seas," in which he stated:

> Until the commencement of deep-sea sounding, as now conducted by the American Navy, the bottom of what the sailors call "Blue Water" was as unknown to us as the interior of any of the planets of our system. Ross and Dupetit Thovars with other officers of the French, English and Dutch Navies had attempted to fathom the sea, some with silk threads, some with spun yard and some with the common lead line used in navigation. All these attempts were made on the supposition that, when the lead reached the bottom, either a shock would be felt or the line, becoming slack, would cease to run out.
>
> The series of systematic experiments recently made upon this subject shows that there is no reliance to be placed on such a supposition.

Maury, an officer of insatiable scientific curiosity, was placed in command of the Depot of Charts and Instruments of the Bureau of Ordnance and Hydrography in 1841. This was the predecessor of our famous Naval Observatory and the present Navy Hydrographic Office. While in this position he instituted the taking of exact measurements of ocean depths and composition of ocean floor by ships of the Navy. These were early of immeasurable value in the laying of the first transatlantic telegraph cable. Hydrographic investigations of the Navy soon became recognized among the foremost works in oceanography and spurred the interest of many persons in this field.[8]

Maury's method, utilized by the Navy, consisted of dropping a cannonball attached to 10,000 fathoms of line, marked every hundred fathoms, and played out from a reel. The depth was determined by the time it took the ball to descend each hundred fathoms and, when the reeling-out for a specific 100-fathom segment exceeded the rate previously established, it was concluded that bottom was reached. His method was improved, in 1854, by one of his assistants, Midshipman J. M. Brooke, USN, by the addition of a bottom-sampling device and a means of releasing the ball

[6] Ibid., October 1944, p. 4.

[7] Ibid., November 1944, p. 4.

[8] Ibid., October 1945, p. 5.

when it reached bottom in order to facilitate recovery of the sounding line.[9]

In 1875 the British scientist, Lord Kelvin, who was associated with Mr. Cyrus Field in the laying of the first transatlantic cable, developed the first practicable pressure tube for measuring depths of less than 100 fathoms. This was improved by Captains Tanner and Blish of the U.S. Navy and later by Capt. G. T. Rude and Mr. F. Fischer, of the U.S. Coast and Geodetic Survey.[10]

The Maury-Brooke deep-sea sounding equipment was improved by Comdr. (later rear admiral) C. D. Sigsbee, USN. His equipment utilized piano wire of great tensile strength as the sounding line and both it and the dipsey lead were hauled in by power. It became standard equipment in the Navy and remained so until outmoded by electronic echo-sounding equipment.[11]

During the last decade of the 19th century Prof. Lucian Blake, of Kansas, made numerous investigations with an underwater bell and microphones in endeavoring to develop an underwater signal system which could provide mariners with warnings of dangers to navigation. The U.S. Lighthouse Board compiled a complete report on his investigations in 1899, after which the matter was dropped.[12]

A short time later, Mr. Arthur J. Mundy, unaware of the work of Blake, began conducting experiments at his residence on Cape Ann, Mass. He also utilized the bell and microphone. He was assisted by Prof. Elisha Gray and Mr. Joshua B. Millet. Their accomplishments led to the formation of the Submarine Signal Co. in 1901. This was the first commercial enterprise organized to conduct underwater sound research and to develop equipment to be used for increasing safety of navigation.[13]

[9] Ibid., p. 6.
[10] Ibid.
[11] Ibid.
[12] Ibid., November 1944, p. 6.
[13] Ibid.

EARLY WORK OF THE SUBMARINE SIGNAL CO.

The major part of the Submarine Signal Co.'s early development work was directed toward the improvement of the microphone. Gray died shortly after the company was formed, after which Mundy was assisted by Mr. Horace B. Gale, who for a time was the company's chief engineer. Later, Mr. Frederick M. Durkee became his associate. The microphone was improved by enclosing it in a metal case faced with a thick diaphragm which carried a "button." The microphone, the button, the telephone receivers, and batteries were connected by a series circuit. The diaphragm of the submerged microphone, agitated by incoming sound waves, varied the resistance of the button which, in turn, varied the current flow in the circuit and caused the telephone receivers to vibrate. The device worked satisfactorily in laboratory tests, but when installed in a vessel for practical tests the noises created by the ship's machinery had more effect upon the microphone than the distantly generated sound waves set up by a submarine bell.[14]

By continued experiments it was discovered that, when the microphone was suspended in a water-filled tank secured to the inside of the hull of a ship, the outside sound waves passed through the metal hull into the tank while the ship-generated noises remained within the hull. This made underwater signaling possible. Moreover, it was ascertained that, with tanks located inside the hull on each bow, a ship could be maneuvered to a course on a line of bearing of the sound waves emitted by the submarine bell by simply equalizing the intensity of the signals set up by the two microphones.[15]

A somewhat crude but practicable navigational aid had this been developed, but curiously enough there existed no market. Shipowners were unwilling to install the microphones unless submarine bells were

[14] Ibid., October 1944, p. 5.
[15] Ibid.

installed. The Lighthouse Board was unwilling to install the bells unless ships were equipped to utilize them.[16]

To demonstrate the practicability of the system, the Submarine Signal Co., with the consent and cooperation of the Lighthouse Board, installed and manned steam-operated bells on *Pollack Rip, Hen* and *Chickens, Nantucket Shoals* and *Boston* Lightships. Mr. Henry Whitney, then president of the company, controlled the Metropolitan Line, which operated four vessels between New York and Boston. These were equipped with listening devices. During this period of demonstration, improvements were made to the submarine bell and to the listening circuit. The rims of the bells were increased in thickness to provide a fundamental frequency of 1,215 vibrations per second. This increased the range of the aid to aproximately 10 miles. The bells could be suspended from lightships, buoys, or by tripods placed on the sea bottom. They could be operated either by steam, compressed air, electric motor, wave motion, or hydraulically. To facilitate use, the telephone receivers were located on the bridge where a switching arrangement was installed to permit the operator to listen alternately to each of the two microphones.[17]

Following these improvements and successful demonstrations, the navigational authorities of the United States and numerous other countries installed the submarine bells at dangerous points of navigation, and the Navy and numerous shipowners quickly installed the receiving circuits. By 1912 there were bells along the coasts of the United States, Canada, the British Isles, France, Portugal, Italy, Brazil, Chile, and China.[18]

UNDERWATER COMMUNICATIONS

Prior to 1912 little thought had been given to the possible use of the system for echo ranging, but endeavors had been made, with Navy cooperation, to develop it into a system of communications for submarines. Many attempts were made to adapt the bell to such usage. But it would not emit sound waves when installed in the flooding tanks of the submarine. Finally, it was discovered that by inverting it above deck it would function properly. However, in this location the compressed air which operated it could not be discharged into the hull because the pressure would be raised too high for human comfort and it was undesirable to vent it to the sea as bubbles would disclose a submarine's position. Moreover, it was difficult to use a telegraphic code with this type of transmitter. In attempting to solve the latter problem many transmitting devices, such as William's water siren, Wood's rotary field electric sounder, and William's longitudinal rod sounder, were experimented with, but with little success.[19]

DEVELOPMENT OF THE FESSENDEN OSCILLATOR

In 1912 disagreements arose between Prof. R. A. Fessenden,[20] chief engineer of the National Electric Signaling Co., and Walker and Givens, its owners, and the former's connection with that company was severed. He then joined the staff of the Submarine Signal Co. In 1914 he succeeded in perfecting an underwater sound oscillator that served both as the transmitter and as the receiver. This device, which emitted undamped waves and could be keyed, revolutionized the use of underwater sound and materially increased the range. The oscillator, weighing about 1,200 pounds, was contained in a watertight case that could be inserted within and fastened to the hull so that the diaphragm was exposed to the sea.[21]

[16] Ibid.

[17] Ibid.

[18] Ibid., p. 6.

[19] Ibid.

[20] Pt. I, numerous citations (index).

[21] Fay, op. cit., December 1944, p. 4.

In signaling in code with this device, it was noted that reflected waves interfered with the reception of the signals. At the time it was not generally realized that these reflected waves could be utilized for ranging purposes. Fessenden believed that they could be used in measuring the distance between the oscillator and the reflecting object and obtained a patent upon such a method. Following the *Titanic* disaster the Government encouraged the development of all ideas which might enhance safety of life at sea. Fessenden's idea was tested with the cooperation of the U.S. Treasury Department which provided the Coast Guard Cutter *Miami* for experiments conducted on the Grand Banks. The tests gave strong indications that a feasible system could be developed, provided the range could be greatly increased.[22]

EARLY NAVY TESTS OF UNDERWATER SOUND FOR RANGING

In 1911 Adm. A. G. Winterhalter, USN, in the U.S.S. *Washington,* conducted experiments in ranging, using sound in both air and underwater as well as radio. While the *Nantucket Shoals* Lightship made simultaneous transmissions of all three types of waves, Winterhalter steamed on various courses and plotted his positions by visual means and by air- and water-transmitted signals against those of radio signals. This was the first attempt to determine distance by acoustics and was the forerunner of one method of conducting hydrographic surveys.[23]

It is of interest to note that on the first leg, on a heading which carried the ship away from the lightship, the whistle signal was lost in 2 minutes 10 seconds at six-tenths of a mile, while the submarine bell continued to be heard for 8½ minutes for an approximate distance of 2 miles. On the second leg, while headed slightly to the southward of the lightship, the submarine signal was picked up when the ship was distant approximately 7 miles and continued to be heard until the ship had passed and had the lightship on her port quarter, at a distance at over 5 miles. On this leg, the whistle was not picked up until almost 15 minutes after the submarine signal at a position when the ship was distant about 3 miles from the lightship and was retained for a distance along the track of approximately 2 miles longer than the bell. When the course was changed to the third and last leg, which placed the lightship fairly sharp on the port bow of the *Washington,* the bell and whistle signals were immediately picked up when the ship completed the course change at a distance of about 8½ miles.[24]

This presents a vivid account of the vagaries of sound transmissions in air, and shows that the submarine sound was more reliable at longer ranges when the ship was headed toward the direction of the emanated waves. More important, it shows that the Navy was conscious of the possibility of submarine sound ranging at a comparatively early date.

EARLY NAVY TESTS OF UNDERWATER SOUND COMMUNICATIONS

As previously stated, the Navy installed Submarine Signal Co. underwater sound receivers for navigational purposes. In 1913, in an endeavor to complement flag signaling and to avoid the undesirable use of radio, sound transmitters were installed in one division of battleships for experimental underwater sound communications. With the division at anchor in Narragansett Bay, off Newport, R.I., perfect signaling was conducted by this method. However, it was slow because of the cumbersome signaling key utilized. The keying also created an annoying noise throughout

[22] Ibid., February 1945, p. 4.

[23] Whitcroff, op. cit., p. 216–217.

[24] Ibid.

the ship that could not be eliminated and was the cause of considerable discomfort to the crew. When underway, the churning of the propellers and the noises generated within the ships interfered to such an extent that further tests were abandoned for surface vessels. Our submariners, learning of the experiments, demanded installations for both detection and for communications between submarines, and the idea was kept sufficiently alive to keep it from becoming a forgotten method.[25]

WORLD WAR I DEVELOPMENT OF SOUND-DETECTION SYSTEMS

When Germany commenced her unrestricted submarine campaign during World War I, it became obvious that we might be drawn into the conflict. To strengthen our preparations, Secretary of the Navy Josephus Daniels in October 1915 established the Naval Consulting Board headed by Mr. Thomas Alva Edison and consisting of the foremost scientists of the Nation.[26] On 10 February 1917 the Consulting Board established a Special Problems Committee with a Subcommittee on Submarine Detection by Sound.[27]

On 17 February 1917, Mr. R. J. W. Fay, second vice president of the Submarine Signal Co., appeared before the Naval Consulting Board, at its request, to discuss submarine signaling and detection. On 23 February members of the Special Problems Committee visited the Submarine Signal Co. plant at Boston, Mass., and witnessed a demonstration of the devices manufactured by that company. On 28 February, Fay wrote Mr. Lawrence Addicks of the Board a letter in which he enumerated the problems confronting the development of a system for the detection of submarines, stated the intense desire of the officials of the company to cooperate, and informed him that these officials had authorized him to obtain a test station at some suitable seashore location, preferably near Boston, and to detail personnel skilled in the art to work exclusively on the project. This letter was enthusiastically received and on 30 March 1917 it was gratefully acknowledged by the Secretary of the Navy.[28]

At this time Fay proposed to Rear Adm. R. E. Griffin, USN, Chief of the Bureau of Steam Engineering, that he invite the General Electric Co. and the Western Electric Co. to participate in the experiments. With Griffin's concurrence, he personally discussed the matter with Mr. Owen D Young, of the General Electric Co., and Mr. Henry B. Thayer, of the American Telephone & Telegraph Co., of which the Western Electric Co. is a subsidiary, and obtained their agreement to work with the Submarine Signal Co. and to respect that company's pioneer interests in submarine signaling upon the conclusion of the emergency.[29] The Western Electric Co. had been working previously on the general subject of submarine detection with the Coast Artillery Corps, U.S. Army, in the vicinity of Fortress Monroe, Va. As a part of that work, this company had planned a fundamental study of the disturbances given off by submarines and an analysis of other disturbances of a similar nature which might be encountered.[30]

When war was declared on 6 April 1917, the experimental station had been established at Nahant, Mass., and was staffed by personnel of the three companies. The initial problem of the Nahant experimenters was to conduct the study which had been planned by the Western Electric Co. and to ascertain the distances these submarine disturbances could be heard.[31]

[25] S. C. Hooper, "How the Navy First Used Underwater Sound," Soundings, May 1945, p. 8.

[26] Annual Report of the Secretary of the Navy, 1915, Washington, Government Printing Office, 1915, p. 45.

[27] Fay, op. cit., May 1945, p. 6.

[28] Ibid., pp. 6–7.

[29] Ibid., p. 7.

[30] "History of the Bureau of Engineering During the World War," Washington, Government Printing Office, 1922, p. 48.

[31] Ibid., p. 52.

During the early days of the war several destroyers were equipped with Submarine Signal Co. underwater sound signaling equipment. Since this was the only equipment available at that time which possessed possibilities of submarine detection, it was proposed that it be utilized. Later, Fessenden developed improved methods and devices which were fitted into the U.S.S. *Aylwin* and U.S.S. *Calhoun*. These destroyers were immediately sent to the war zone to conduct service tests and the equipments provided fair but insufficient detection.[32]

Meanwhile, the Submarine Signaling Co. developed an extremely sensitive microphone which, when hung in the water, would receive distant noises as strong as they could be received by the Fessenden oscillator even when amplified by a vacuum tube amplifier. The only difficulty was that it was even more sensitive to nearby sounds. It was found necessary to suspend the microphone to a float attached to the ship by about 200 feet of cable. This eliminated noises generated on board ship and by water lapping against the ship's hull. By shutting down the ship's machinery and drifting, it was possible to detect noises generated at considerable distances from the listening vessel. This became known as the drifter set.[33]

In May 1917 the Bureau of Steam Engineering assembled a group of scientists in Washington to consider a number of proposals involving magnetic detection. The members of this group were proposed by Dr. R. A. Millikan, Chairman of the Anti-Submarine Committee of the National Research Council, and consisted of Profs. Ernest Meritt, Cornell University; A. C. Lunn, University of Chicago; H. A. Bumstead, Yale University; Dr. L. A. Bauer, Carnegie Institution; and Mr. W. H. Nichols, of the Western Electric Co. The Committee submitted nine possible methods, several possessing sufficient potential to warrant development. However, they rendered the unanimous opinion that magnetic detection was limited in range. As a result of this opinion, it was decided that other methods must be also attempted.[34]

On 8 May 1917, Secretary of the Navy Daniels held a conference in Washington on the subject of submarine detection attended by representatives of the General Electric Co., the Western Electric Co., and the Submarine Signal Co. Following this conference the Secretary, on 11 May, created the Special Board on Antisubmarine Devices. This was composed of Rear Adm. A. W. Grant, USN, and Comdrs. C. S. McDowell and M. A. Libbey, USN, and "was appointed for the purpose of procuring, either through original research, experiment, and manufacture, or through the development of ideas and devices submitted by inventors at large, suitable apparatus for both offensive and defensive operations against submarines." Dr. Millikan, of the National Research Council; Dr. W. R. Whitney, of the General Electric Co.; Dr. F. B. Jewett, of the Western Electric Co.; and Mr. Fay, of the Submarine Signal Co., were appointed as advisory members. The Board was directed to cooperate with the above-mentioned companies and with all others whose experience and facilities might prove especially beneficial in solving the problem. The organization meeting was held in Boston, Mass., in June 1917, and at that time plans were drawn up to provide coordination of all activities engaged in the project.[35]

On 1 June 1917, the National Research Council convened a meeting of scientific representatives of England and France, personnel of the Navy Department and of the three above-mentioned companies, and of professors and other individuals who had evinced interest in the subject of submarine detection. The foreign representatives explained developments abroad and suggested problems which might be investigated in this country for the improvement of their devices. Sir Ernest Ruther-

[32] Ibid., pp. 52–53.

[33] Fay, op. cit., May 1945, p. 8.

[34] "History of the Bureau of Engineering During the World War," op. cit., p. 48–49.

[35] Ibid., p. 48.

ford described the results that he and other British experimenters had obtained with a binaural system, but stated that they had failed to develop satisfactory directional devices. The experiments of Professor Langevin of France in producing intense underwater sounds, using a technique developed by Pierre Curie, were discussed. This involved passing an alternating current of approximately 15 kc. through a quartz crystal, causing it to vibrate and propagate sound waves. Langevin used alternate slabs of quartz and steel plates for his underwater transmitter which emitted sound waves in a narrow beam. The Watzer apparatus, as developed in France, was also described. This apparatus stimulated certain original ideas which later led to the development of one of our best acoustical devices.[36]

Following this meeting, the National Research Council recommended that certain scientists be brought together to work on the problems that had been generated. Acting upon this suggestion, the following additional groups were formed:

The New York group, under the direction of Prof. M. I. Pupin, of Columbia University, was assigned work in supersonics. This group conducted its studies at New York, Key West, Fla., and New London, Conn.;

The San Pedro group, under Mr. Harris J. Ryan, was also assigned work in supersonics and similar lines of research;

The New London group under the chairmanship of Dr. A. A. Michelson and the vice chairmanship of Professor Merritt, was assigned work on binaural devices. Other leading members of this group were Prof. H. A. Bumstead, of Yale University; M. Mason, of the University of Wisconsin; G. W. Pierce, of Harvard University; and Harvey C. Hayes, of Swarthmore College; and

The Chicago and Wisconsin groups, which were assigned various problems in support of the other groups.[37]

Independent work by numerous individuals was conducted in magnetic detection under the supervision of Maj. R. D. Mershon and in light detection under the supervision of Dr. H. E. Ives.[38]

ACTIVITIES OF THE SPECIAL BOARD

The Special Board provided the necessary liaison between these scattered activities in order to eliminate undesirable duplication of effort. It acted as a clearinghouse for all information concerning submarine detection so that all concerned had available a complete record of accomplishments. When alternate lines of development appeared promising, the Board allocated the various phases to the several groups and individual investigators, and established schedules in order that parallel progress was maintained in all phases. It was necessary that the Board schedule and witness all tests and then make recommendations as to the suitability of the various developments. Once a device was recommended, it was necessary for them to cooperate with the various companies to assure that the device was properly engineered for quantity production and, afterward, to insure that production was scheduled to meet the needs of the Navy and our Allies.[39]

In compliance with the directive, many of the country's manufacturing companies were invited to cooperate. In addition of the General Electric Co. the Western Electric Co., and the Submarine Signal Co., the following firms gave wholehearted assistance in providing urgently needed apparatus or material: United Wire & Supply Co. of Providence; Westinghouse Electric & Manufacturing Co.; Victor Talking Machine Co.; Locomobile Co. of America; Ford Motor Co.; Willys Overland Co.; Standard Parts Co. of Cleveland; Bryant Electric Co.; Worcester Polytechnic Shops; and Pittsfield Machine & Tool Co.[40]

[36] Ibid., pp. 50–51; "Sonar" (Navy Department press release, 6 Apr. 1946), p. 2.

[37] "History of the Bureau of Engineering During the World War," ibid., pp. 51 and 61.

[38] Ibid., p. 53.

[39] Ibid., pp. 60–61.

[40] Ibid., p. 68.

During the summer of 1917, such rapid progress was made on the solutions of the various problems and in development of devices that it became necessary for the Board to procure the services of several of the country's leading physicists and engineers as consultants. The need for added testing and shop facilities resulted in the augmentation of the New London group and its redesignation as the Naval Experimental Station.[41]

This station was established at New London, Conn., in September, in an abandoned shop adjacent to the Fort Trumbull Millitary Reservation. The building housed a completely equipped machine shop initially operated by six enlisted personnel. Shortly thereafter additional buildings were completed to accommodate the ever-increasing personnel and to provide offices and laboratories for the scientists. A nearby marine railway was rebuilt to haul out the vessels to facilitate the installation of equipments for the numerous tests. Mr. S. W. Farnsworth, an experimental engineer of the Westinghouse Electric & Manufacturing Co., was graciously loaned by that firm to organize the station and get it in operation. His services were invaluable. By the end of the year its complement was 200 persons.[42]

Continued increase in the work of the Board resulted in constant expansion of the station. New buildings were erected and civilian experts from all parts of the country were called in to assist in designing and engineering the several devices. A separate department was formed to relieve the research and development scientists of the functions of service testing and comparing the merits of the devices submitted. Extensive facilities for the required tests were provided by augmenting the previously assigned three converted steam yachts with the destroyer U.S.S. *Jouett* and three submarine chasers. As required, the submarine base at New London provided submarines as target vessels. Installations of practically every type of detector developed were made on the *Jouett,* and valuable information was obtaining concerning the applications of these for services usage. By the time the armistice was declared the station had expanded to provide facilities for a complement of 700 person.[43]

In January 1918, Capt. J. T. Tompkins, USN, Office of the Chief of Naval Operations; Capt. A. J. Hepburn, USN, in command of the base at New London, Conn.; and Comdr. E. C. S. Parker, USN, in charge of the tactical group at New London, were appointed as additional members of the Special Board. Tompkins provided liaison between the Navy Department and the Board; Hepburn took charge of equipping submarine chasers and training their listening crews; while Parker cooperated, through the tactical group, in developing the tactics and methods of operation of the submarine chasers. In May 1918, Parker was succeeded by Capt. W. P. Cronan, USN. In July 1918, Hepburn was assigned to command the Queenstown, Ireland, group of submarine chasers. He was relieved as a board member by Capt. W. T. Tarrant, USN. In September 1918, McDowell was ordered to London and was relieved as member and secretary by Capt. J. R. Defrees, USN.[44]

In order to provide still closer cooperation between the Navy Department and the Board, the following officers were named as additional members in May 1918: Lt. Comdr. G. K. Calhoun (Math). USN, Bureau of Steam Engineering; Lt. Comdr. P. S. Wilkinson, Jr., USN, Bureau of Ordnance; and Lt. Comdr. H. R. Bogusch, USN, Bureau of Construction and Repair.[45]

ACCOMPLISHMENTS OF THE GROUPS

Numerous sound-interception devices were developed during the war and many of

[41] Ibid., pp. 54–55.
[42] Ibid., p. 55.
[43] Ibid., p. 59.
[44] Ibid., pp. 58–59.
[45] Ibid.

these were engineered for quantity production. The most important of these were the C-tube, an acoustical device developed by the Nahant group, and the MV-tube, an electrical system developed by the New London group.

As originally developed, the C-tube was an aural device consisting of two rubber spheres, 3 inches in diameter, mounted 5 feet apart on the ends of an inverted T-shaped hollow pipe that terminated in a stethoscope. The device was hung over the side or protruded through the bottom. The vertical shaft of the T was fitted with a wheel by which the whole assembly could be rotated until the sound seemed directly in front of the listener who then read the relative bearing, normal to the line of the two spheres, from an affixed scale. It was necessary to stop and quiet the searching ship before outside sounds could be heard since the rubber spheres were not exceedingly sensitive, and the apparatus suffered the same handicaps of other detection devices close to the ship. Later, the C-tube device was enlarged to provide six or more spheres on each of the inverted ends of the T.[46]

Following the development of the C-tube, the Nahant group endeavored to embody the binaural principle into the drifter set. The problem involved was to devise a means by which the sounds from the several receivers would arrive at the listener's ears simultaneously. It was solved by the development of a "compensator," a device for indicating the angle of incidence of a sound wave relative to a baseline containing two or more receivers. This was designated the K-tube Set. It consisted of three microphones arranged in an equilateral triangle, any two of which could be used simultaneously. Electric cables connected the mircophones to two telephone receivers located at the listening station within the ship, one being the left, and the other being the right receiver. The telephone receivers were coupled to the operator's ears by the flexible air lines which could be varied in length by a wheel and the amount of this variation was transferred to a dial calibrated in degrees. Just as the bilateral radio direction finder did not indicate whether the bearing or its reciprocal was correct, it was necessary to pair the third microphone with either of the two previously used to determine the sense.[47]

The K-tube set was used quite extensively during the war, but it was of little value other than for initially locating submarines since it could not be used for continuously hunting them down and destroying them. In an effort to develop this set for such expanded use, the company designed three types of towed devices designated OS, OK, and OV. These operated in exactly the same way as the K-tube set, but were designed to be towed at high speeds without introducing noises created by water motion. The float supporting the microphone was designed to maintain its submerged depth at all speeds and to maintain its microphone base line relative to the towing ship at all times. These developments were primarily the work of Drs. Irving Langmuir and W. D. Coolidge and Mr. C. E. Eveleth.[48]

The MV-tube set was proposed by Mason on 3 July 1917. It was based upon original ideas conceived by him after hearing the descriptions of the Langevin and Watzer devices. As finally developed, it was an electrical sonic system of 12 carbon button-type microphones, contained in a blister on each bow, which fed the sounds through phased circuits to a compensator which gave the direction of the received sound within a few degrees. This was the first listening apparatus which, when located within the hull of a ship, permitted the reception of sound waves emitted from a source a fair distance away. Its develop-

[46] Fay, op. cit., July 1945, pp. 6–8; "Sonar," op. cit., p. 1–2.

[47] Ibid.

[48] "History of the Bureau of Engineering During the World War," op. cit., p. 61.

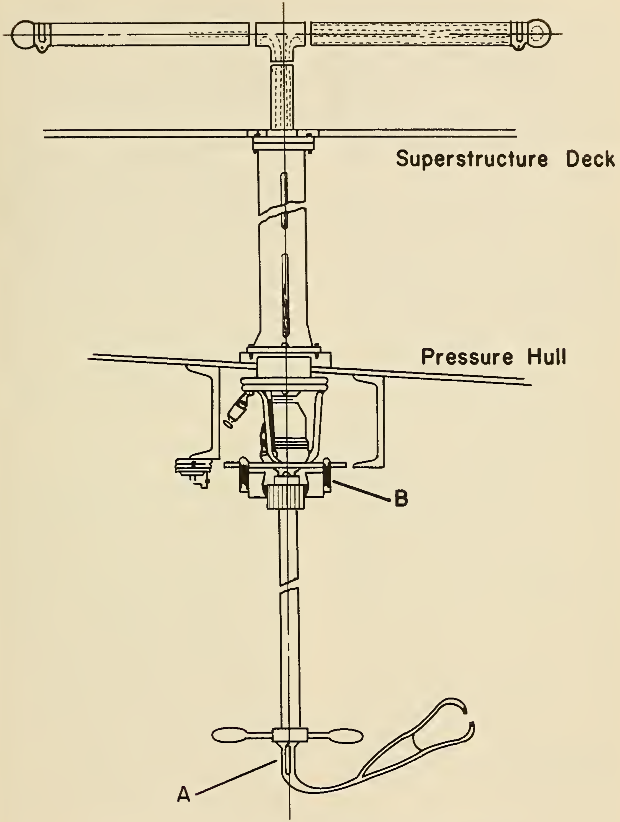

FIGURE 26–1. First Navy Sonar—World War I complete listening apparatus.

ment eliminated, to a large extent, the necessity of using towed devices. Nonresonant receivers were used because they possessed the advantage of lack of sensitiveness to other than the natural frequency of the receiver diaphragm, a desirable factor since submarines emit sounds covering the entire audible frequency range. Morever, they can be used binaurally, because they reproduce phase with fidelity.[49]

Despite the large amount of research conducted on acoustical detecting devices, it was well realized that the ultimate equipment would have to be mounted entirely within the hulls of vessels equipped for submarine hunter-killer operations and yet not be subjected to ship-generated noises. Work on this problem carried on at the Boston factory of the Submarine Signal Co. aided in the ultimate development of the multispot system. Just prior to the termination of hostilities, two destroyers were equipped with a device that included four Fessenden oscillators located in the forepeak tank. Screens were placed between these oscillators so that each responded to sound waves coming from a single quadrant. Two adjacent oscillators were listened to at one time, and the operator determined the direction from which the sound emanated by relative signal intensities.[50]

The problem of detection of submarines at rest was studied by a number of individual investigators and by several of the groups. Professor Merritt was working on the problem at New London at the time the Special Board was created, and he continued to follow the progress of the several schemes attempted until the close of the war. By midsummer of 1918, he had developed a short-range device designated the AD-tube. Dr. Vannevar Bush developed a device for this purpose, known as the audio telegraph, and, although it was engineered for quantity production, it was never put into general use. The Chief Engineer of the Westinghouse Electric & Manufacturing Co., Mr. B. G. Lamme, undertook similar investigations prior to our entry into the war and developed an apparatus which was undergoing service tests at the end of the war.[51]

Detection devices such as the "electric eel," which consisted of several microphones encased in a long rubber tube, and the OK-tube, were developed for lowering from dirigibles and towing underwater. The PB-tube was developed for use by seaplanes drifting upon water. This consisted of three microphone units suspended separately from three rings on the plane's bow in such a manner as to form a triangle. The "electric eel" was also used for this purpose. All of these devices were used with compensators.[52]

The Western Electric Co., in cooperation with officers of the Special Board, developed two separate methods of harbor-entrance submarine detection. One method consisted of 20 microphones, each supported on a tripod, connected by a single cable. Any one of these could be utilized by means of a selective switching system. Since only one could be utilized at a time the system was nondirectional and the submarine's location could only be determined approximately by its nearness to a particular microphone. Later, the binaural principle was adopted, each tripod being equipped with three microphones. An electric compensator and an audiofrequency amplifier were located at the listening post on shore. The submarine cable used in this installation was especially designed to maintain both circuits of the binaural system equal in electrical characteristics. Installations had been completed and were in operation at the entrances of Long Island Sound and the Chesapeake Bay when the armistice was declared. Equipment had been ordered for additional in-

[49] "History of the Bureau of Engineering During the World War," op. cit., pp. 51, 59, 62–66; "Sonar," op. cit., p. 2.

[50] Fay, op. cit., July 1945, p. 8.

[51] "History of the Bureau of Engineering During the World War," op. cit., pp. 67–68.

[52] Ibid., p. 69.

stallations along the Atlantic coast. One complete system was provided the British and was being installed at the time of the armistice.

The second method consisted of a system of magnetic loops, the forms of which varied with the contour and configuration of the areas where laid. These loops were connected to galvanometers on shore which indicated the passage of a submarine over each loop. The exact position of the submarine was determined by the sequence of the deflections received from the different leads. The loops were of short range and, therefore, confusion was not caused by a large number of vessels in the vicinity. Hence, this system served as an adjunct to the first method. It had been installed and was in operation at the entrance to Chesapeake Bay prior to the termination of hostilities. Mr. E. H. Colpitts, noted electronic engineer of the Western Electric Co., was responsible for these developments.[53]

TRAINING IN THE USE AND MAINTENANCE OF UNDERWATER DETECTION EQUIPMENT

The successful use of early types of underwater detection equipment depended largely upon the skill of the operating personnel and the tactics employed by the antisubmarine vessels. Since these equipments provided only the direction of the sound source, determination of its location necessitated triangulation by vessels working in groups of three or more. As the devices were more accurate when the vessels were dead in the water, this decreased the effectiveness of the hunters. Further complications in attacking an unseen object with depth charges necessitated the entire group to use pattern firing at the enemy targets, which used all the evasive tactics at their command. Successful hunter-killer procedure involved ship handling, navigational plotting, instantaneous communications between the ships of a group, and coordinated attack. The submarine chasers were initially manned by untrained crews, and this provided the opportunity for training along the necessary specialized lines. The destroyers presented a more difficult problem. Their use in protecting convoys outweighed all other considerations and time could not be devoted to the hunter-killer training. It was necessary to provide them with the equipment and let them work out their own doctrines and procedures.[54]

The individual operators were trained at a school established at New London in September 1917. This school was equipped with the various types of equipment as they became available and was assigned vessels to provide the operators with actual seagoing experience using our own submarines as sound targets. Between the date of its establishment and the signing of the armistice the school trained over 1,500 operators. With the increasing number of installations, it became apparent that a number of officers would be required to supervise their installation and maintenance. A trial class of 50 officers was formed in July 1918 and favorable results were obtained from this training. In September 1918 the Hydrophone School was established at New London. During the 3 months of its existence it trained approximately 150 additional officers.[55]

OPERATIONAL USE OF UNDERWATER DETECTION EQUIPMENT

The purpose of the campaign against German submarines was to make the Atlantic safe for the transport of our military forces and the enormous logistic tonnage neces-

[53] Ibid., pp. 69–71.

[54] Ibid., pp. 57–58.

[55] Ibid., pp. 54, 59.

sary for the prosecution of the war in Europe. While complete safety was not achieved, the devices developed did aid the Allied Forces in containing the menace. In some areas, especially along our coasts, German submarine operations ceased. The destruction of at least six submarines was credited to the use of American-developed antisubmarine equipment. Each submarine destroyed was the equivalent of an annual saving of 40,000 tons of shipping, representing a value of about $150 million. Thus, sinking of six submarines represented a annual saving of approximately $900 million as compared with the $2 million which was expended annually for research and development of the equipment. However, the major contribution of improved detection devices was the lowering of the morale of the German submariners.[56]

Our own submarines universally welcomed the installation of sound-detection devices in their vessels. Such devices complemented the periscope when they were submerged, permitted them to detect and avoid collision with friendly craft, and aided in the detection of enemy ones.[57]

Sound-detection devices were used extensively by convoy commanders to insure that the vessels being convoyed did not straggle or fall behind during darkness and also for the purpose of avoiding collisions during periods of poor visibility.[58]

In retrospect, the underwater detection devices developed during World War I seem crude and inadequate compared with present-day sonar equipment. However, when one considers that extremely little had been accomplished before our entrance into the war, that only comparatively crude electronic amplifiers were available, and that during peacetime the normally accepted period between the conception of an idea and the installation of equipment is 5 years, one must admire the endeavors, persistence, and accomplishments of the personnel engaged in improving these devices under the supervision and direction of the Chief of the Bureau of Steam Engineering.

[56] Ibid., pp. 72–73.

[57] Ibid.

[58] Ibid.

POSTWAR DEVELOPMENT

Following the termination of hostilities all of these groups, excepting the Naval Experimental Station, were disestablished and only a few of the top scientists remained. These were headed by Hayes, who, before the war, had been professor of Physics at Swarthmore College where he had become interested in underwater sound and had conducted numerous experiments using the college swimming pool and the noises generated by trains traveling a railway adjacent to the campus.[59] Because of his previous work and experience he had been chosen as one of the New London group scientists. His decision to continue in this field was most fortunate for the Navy because his efforts were primarily responsible for the development of the present-day sonar.

Prior to the war, Fessenden demonstrated that soundings could be obtained with his apparatus in deep water, but it was incapable of measuring the small interval of time involved in shallow-depth measurements. His initial method was the transmission of nine dots, one-fifth of a second apart. Counting the number of dots which returned and allowing 80 fathoms per dot gave the approximately depth. If all nine dots were echoed, the depth was in excess of 640 fathoms. The wartime activity of the Submarine Signal Co. did not permit further immediate development of this system of depth measurement.[60] Later, single pulses were resorted to, and the time from transmission to receipt of echo was measured by a stopwatch calibrated in fathoms.[61]

[59] Whitcroff, op. cit., p. 217.

[60] Fay, op. cit., December 1945, p. 7.

[61] H. C. Bailey, "The Evolution of Deep Sea Sounding Methods" (Journal, American Society Naval Engineers, 1951), p. 357.

NAVY DEVELOPS FIRST PRACTICABLE SONIC DEPTH FINDER

In late 1918 the transport U.S.S. *Von Steuben* was equipped with MV-tube apparatus. The war being at an end, it was decided to test this apparatus as an aid in the prevention of collisions at sea. In March 1919 the ship left New York with Hayes aboard to conduct the tests. Upon departure, the equipment worked perfectly, detecting and giving the positions of all ships near the transport. This good performance continued until the ship reached the Continental Shelf, at which time it apparently ceased to function. The equipment was thoroughly overhauled and checked, but it still did not work. A watch was maintained for the remainder of the Atlantic crossing with negative results, until early one morning when approaching the French coast the operator notified Hayes he was picking up the propeller noises of the *Von Steuben* but that they appeared to be coming from amidships instead of astern.[62]

Hayes deduced that the failure to pick up the ship's noises during part of the passage was due to the fact the sounds were being directed down and reflected back from the bottom and that in the deeps the echoes were lost. This led him to experiment with the equipment as a depth-finding device. The equipment was mounted so that it could be trained to determine the angle at which reflected propeller noises arrived at the receiving apparatus. The angle determined, a simple trigonometric formula was applied, thus providing the depth. On the return voyage the *Von Steuben* approached Long Island in a dense fog, taking soundings with this instrument and setting courses conforming to the obtained soundings as compared to those of the chart, and made a perfect landfall on *Ambrose Light*. Later the apparatus was improved by utilizing a Fessenden submarine oscillator which provided a stronger and more readily identifiable signal and by calibrating the indicating scale in fathoms.[63]

Following Hayes' return from the *Von Steuben* voyage, the Naval Experimental Laboratory was moved to Annapolis, Md., and consolidated with the Naval Engineering Experimental Station. There Hayes and his assistants began work to improve the sonic depth finder. With the Fessenden oscillator and the MV hydrophones he had all that was necessary for a sonic depth finder except an accurate timing device. By early 1922 he succeeded in developing such a device.[64]

Meanwhile, several tests were made using Hayes' angle-of-reflection method. In January 1920 the U.S.S. *Breckinridge* ran a comparative line of soundings from Charleston, S.C., to Key West, Fla., using both this method and the dipsey lead, and it was determined that the sonic equipment gave more accurate measurements. Another test by the U.S.S. *Blakely* in May 1920 produced similar results. Both these tests indicated that, in water deeper than 100 fathoms, the sonic depth finder readings using the angle-of-reflection method became unreliable because the reflection angle became too acute.[65]

Following the development of the timing device, the equipment was installed in the radio experimental ship, U.S.S. *Ohio,* with the idea of ranging between two ships. One of the ships was to generate underwater sound and at the same instant transmit a radio signal in a manner similar to the 1911 U.S.S. *Washington-Nantucket Shoals Lightship* experiment. The other was to receive both signals and, by computations of time and speed of radio and underwater sound, determine the distance of the transmitting ship. A second ship was not made available; therefore it was decided to test the time-measuring device by reflecting the sound waves generated by

[62] Whitcroff, op. cit., pp. 217–218.

[63] Ibid., p. 218.

[64] Ibid., pp. 218–219.

[65] Ibid., p. 218.

the *Ohio* off the ocean floor. In February 1922 she departed New York for Annapolis Roads Md., to test the apparatus. This test proved that a workable deep-sea sonic depth finder had been developed. Soundings on known bottoms in excess of 1,700 fathoms were made and compared. On the approach to the Virginia Capes a heavy fog was encountered and the ship was safely navigated into the Chesapeake Bay on soundings.[66]

At this time destroyer reliefs for the Asiatic Fleet were being readied and it was decided to equip one of these, the U.S.S. *Stewart,* with the apparatus for the purpose of making a continuous profile of the ocean floor from the United States, eastward through the Mediterranean, the Indian Ocean, and up the west coast of China. In June 1922 the *Stewart* departed Newport, R.I., with Hayes aboard to direct the use of the apparatus and to insure that it functioned properly. He left the ship at Gibraltar and, from thence on to Chefoo, China, the soundings were conducted by the ship's officers and crew. Continuous soundings of the ocean floor were made for somewhat over 6,500 miles. This was the beginning of increased work in oceanography, to which the Navy has contributed over one-half the data. The Navy's deep-sea sonic depth finder was, like its sister, the earlier shallow-water depth finder, the direct byproduct of the submarine detection and ranging problem.[67]

DEVELOPMENT OF UNDERWATER DETECTION AND RANGING FOLLOWING WORLD WAR I

During the war it was realized that the ranges could be improved if a higher frequency oscillator and receiver could be developed. Therefore, considerable research was conducted in supersonics. In 1918 it was suggested that the piezoelectric property of quartz crystal might be utilized to produce a supersonic oscillator. The Royal Navy began the development of such a device and constructed a laboratory model which utilized sandwich arrangements of quartz and steel. This was a rather crude device and, like the Submarine Signal Co. devices developed by the Nahant group, it had to be suspended in the water by hanging it over the side. Despite this, great increases in ranges were obtained. The termination of the war separated British and American exchange of research information on this subject. The British Navy adhered to the quartz-steel development which became known as ASDIC, the abbreviation for the Antisubmarine Detection Inventions Committee; and the U.S. Navy continued its endeavors to improve the Fessenden oscillator.[68] Later, the Navy, in 1927, abandoned the oscillator and developed the transducer which[69] consisted of a battery of ferronickel alloy tubes driving a steel plate by magnetostriction.[70]

The underwater sound group was moved from Annapolis to the Naval Research Laboratory in 1923, where 20 scientists, working under the direction of Hayes, continued their endeavors to develop a supersonic echo-ranging system employing electronic amplification. Their ultimate success will be related in a later chapter.

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[66] Ibid., p. 219.

[67] Ibid., pp. 222–232.

[68] Maurice Prendergast, "Sonar and Asdic" (U.S. Naval Institute Proceedings, August 1948), p. 1009.

[69] Monthly Radio and Sound Report, Bureau of Engineering, May–June 1927, p. 12.

[70] This type of transducer utilizes the Joule effect wherein the dimensions of ferromagnetic objects are changed when placed in a magnetic field. Definite and fixed frequencies, usually above audibility, may be generated by such a device.

CHAPTER XXVII

Attempts to Establish a United States Government Radio Monopoly

BRITISH ENDEAVORS TOWARD ESTABLISHMENT OF WORLD DOMINANCE IN RADIO COMMUNICATIONS.

England, long dominant in cable communications which, with her monopoly of sea transportation, had been utilized for the expansion of the Empire's world trade, was quick to see the necessity of having her nationals in control of radio communications. Germany, refusing to accept a British monopoly, arranged for and called the first International Radio Telegraph Conference in 1903 in an endeavor to obtain international agreement for the control of the new medium of communications. This country sent delegates to this Conference who did much to further such agreement. However, our Congress took no action to prevent foreign interests from obtaining a foothold in this country. By 1912 this shortsightedness, combined with the unscrupulous methods of radio stock promoters, resulted in the survival of only one important American radio operating company, the Marconi Wireless Telegraph Co. of America, a subsidary of British Marconi. The objections of the Marconi interests to any legislation, national or international, which would have controlled their operations have been related in the preceding chapters.

It is most probable that, except for World War I, the Marconi Co. would have continued to expand and would have become the dominating factor in world radio communications. Existing resentment against the British control of communications was intensified in this country by the wartime severing of the cables connecting the United States and Germany which forced the use of radio for the conduct of business, diplomacy, and for the reception of news from that country.

During the war the American Marconi Co. attempted to promote the belief that a substantial percentage of its stock was American owned but when the U.S. Shipping Board demanded they provide an affidavit showing that more than one-half its stock was owned by U.S. citizens, they were unable to do so.[1]

The war temporarily eliminated the Marconi interests from the American commercial radio business but, with an eye to the future, they made all possible efforts to obtain patent rights on all available continuous wave transmitting equipment, having become convinced that the day of the spark had passed, regardless of improvements which might be made to make its gap sing more sweetly. In 1915 the parent Marconi Co. conducted negotiations with the General Electric Co. for the purchase and exclusive use of Alexanderson alternators for their long-distance circuits. These efforts were discontinued because of wartime pressure on British foreign exchange.[2]

[1] The Radio Industry, 1923 Federal Trade Commission hearings (Washington, Government Printing Office, 1923), Testimony of Mr. Lewis MacConnich, p. 885.

[2] W. Rupert Maclaurin, "Invention and Innovation in the Radio Industry" (the Macmillan Co., New York, 1949), p. 100.

Later they attempted to purchase the arc transmitter patents of the Federal Telegraph Co.

ATTEMPT TO REVISE THE ACT TO REGULATE RADIO COMMUNICATIONS

On 21 November 1916, an Interdepartmental Radio Committee draft of proposed radio legislation was informally discussed at a meeting of interested commercial and Government operating interests arranged by the Department of Commerce. The provisions of this draft materially increased governmental control over that authorized by Public Law 264 of 1912. The most important changes, which are given below, were opposed by the Marconi Co., represented by their vice president and general manager, Mr. E. J. Nally, who opened his discussion with the complaint that his company had only a limited time to study the effects of the proposed legislation.[3]

Section 5 contained the provisos that Government stations could be opened to the general public business and that the Secretary of Commerce could fix the rates charged by commercial companies. Nally objected to both of these provisos on the grounds that, if enacted into law, the Government would be in competition with private interests and that, since their rates would not be subject to the ruling of the Secretary of Commerce, they could undercharge in an effort to eliminate private competition.

Section 6 contained the proviso that the Government, through the Navy Department, could acquire, by purchase at a reasonable valuation, any coastal radio station then in operation in the United States which the owner desired to sell. Nally stated that this indicated the Government's desire to eliminate commercial interests and that the proposed bill did not stipulate who should determine the reasonableness of the valuation of the properties.

The last paragraph of section 7 provided that no license should be granted a new station if, in the opinion of the Secretary of Commerce, it would seriously interfere with an existent Government or commercial station in the vicinity. The penultimate paragraph of section 8 sought to vest further licensing authority in the same official by permitting him to determine in advance of construction whether the installed apparatus would be licensed. The Marconi spokesman opined that this would stifle the growth of the radio art as the opinion of one person could prevent the use of a newly developed apparatus.

The first paragraph of section 9 provided that the President, at his discretion, could close stations, remove their apparatus or authorize their use as Government stations upon just compensation to its owners. Public Law 264 of 1912 authorized such action "in time of war or public peril or disaster." In opposing this, it was stated by the Marconi Co. that it had, at previous times, voluntarily offered its complete organization to the Government for use in war or national emergency and that it could not see the necessity for extending these powers to the President in time of peace.

Section 10 permitted the officials of the Department of Commerce to inspect the records of all commercial companies. The Marconi Co. contended that this should be limited to records pertaining to the transmissions of messages and the installed equipments.

Section 11 included a requirement for the employment of licensed persons in the operation or supervision of a station. This was objected to since it necessitated the obtaining of licenses by engineers who might not necessarily be radio operators.

Public Law 264 required a logarithmic decrement not in excess of two-tenths per complete oscillation except when transmitting distress messages. Section 17 of the proposed legislation provided that the

[3] "The New Radio Legislation," The Wireless Age (Marconi Wireless Telegraph Co. of America), January 1917.

Secretary of Commerce could specify the decrement. The Marconi official believed this would give ground for controversies since it was not, at that time, possible to determine in advance what the actual decrement of a new station would be.

The Marconi Co. contended that the requirements of section 20 which prohibited commercial use of frequencies between 75 and 1,500; section 21 which restricted the number of frequencies allowed for commercial ship-shore communications; and section 23, which further limited the number of shore stations which could be licensed and prevented changing equipment in existent ones, manifestly favored Government operation at the expense of the commercial companies. Nally considered that the drafters of the proposed bill were attempting to solve the interference problem by limiting the numbers of stations and restricting the use of frequencies instead of conducting research to remove the causes.

He closed his denouncement by stating:

> In general the proposed bill is evidence of a desire to limit private enterprise, and tends to discourage and suppress individual efforts to promote or advance the radio signaling art. For the reasons stated as well as for other technical considerations, the Marconi Company desires to record its protest against the provisions of the bill under consideration.[4]

Prof. Arthur E. Kennelly, of Harvard, president of the Institute of Radio Engineers, submitted a communication which was read by Mr. David Sarnoff, the institute's representative. He said that he was mainly interested "in the active development of the science and art of radio communication in America as a scientist, a teacher, an operator, a telegraphist and a United States citizen." Continuing his remarks he stated, in substance, that since it was the Government's duty to protect American enterprise and capital the Congress should oppose any legislation regulating the industry since such regulation in peacetime could degenerate into the confiscation of private property or might force existing companies from the business. He further contended that regulation could retard incentive and development as it had done to the Government-owned systems of several European countries.[5]

Similar protests were voiced by Prof. Alfred N. Goldsmith of the College of the City of New York and Sarnoff, himself.[6]

The attitude of the commercial interests toward what they considered an attempt to eliminate them from the business was reported in the Wireless Age of January 1917:

> The general trend of the discussion disclosed the feeling that in this bill was evident a distinct spirit of hostility towards existing wireless organizations. Criticism was leveled at the proposal to confer power upon government departments to compete with commercial stations operated by American citizens, and at the same time dictate the terms of regulation. It was asserted that the quickest way to stifle inventive effort would be to permit government competition or confiscation to destroy the market for private enterprise; furthermore that this was an unpatriotic action, since it is perfectly obvious that encouragement and aid should be given to promote invention in the art, so that the United States should have the best obtainable system in time of need.
>
> Proposals to restrict the operation of commercial stations in time of peace and to impose handicaps which would prohibit operation of these stations were unanimously opposed by all representatives at the meeting.

FROM REGULATION TO ATTEMPTED GOVERNMENT MONOPOLY

Despite the strenuous objections of the Marconi interests and the leading radio engineers of the country, the proposed legislation, virtually unchanged, was transmitted to the House of Representatives. It was introduced by Congressman Joshua W. Alexander of Missouri, chairman of the Committee on the Merchant Marine and Fisheries, and became House Resolution 19350, commonly known as the Alexander bill.

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[4] Ibid.

[5] Ibid.

[6] Ibid.

Secretary of the Navy Daniels, in a letter dated 26 December 1916, announced the Government's position, stating that the Alexander bill was aimed at the elimination of commercial interests from the ship-shore radio communication business. He further recommended that Congress provide for the purchase of all existing commercial stations in the United States, Alaska, Hawaii, Puerto Rico, and Swan Island within 2 years and that no additional stations be licensed for commercial operation. He based his actions upon the necessity of eliminating interferences, duplications of efforts, and unsatisfactory radio discipline, and closed his letter by stating that radio stations must be in Government hands before the first hint of possible hostilities.[7]

Open hearings on the bill commenced before the Alexander Committee on 11 January 1917 with the presentations of its proponents. These were followed one week later by those of the opposition, led by the Marconi Co., assisted by numerous radio engineers and by all the amateur associations except the American Radio Relay League. The latter, headed by Mr. Hiram Percy Maxim, vigorously supported the measure much to the surprise of the other amateur organizations. Spirited debate occurred over the provisions of the bill that would have limited the percentage of the stock of any operating commercial company which might be alien-owned and the prohibition of against alien officers of such companies. At the Department of Commerce hearings, Nally had ignored this proviso because he did not care to divulge the percentage of foreign-owned American Marconi stock. The Marconi interests again marshalled their full strength in denouncing the provision which would permit Government radio stations to handle commercial traffic.[8]

Prior to the completion of the hearings, diplomatic relations with Germany were severed, Government officials became deeply engrossed in other business, and the bill was not reported out of committee. On 7 April the Navy assumed operational control of all radio stations, thus removing the immediate need for action. Nevertheless, Secretary Daniels constantly endeavored to obtain the congressional approval he desired.

The actions of the Marconi officials further convinced Government officials that England was intent upon establishing her dominance in this field when the war should end. They were equally convinced that it was necessary to eliminate British influence from American commercial radio operations and further, if possible, to establish Government monopoly and American dominance in the field. With this in mind, and using wartime necessity as a reason, they proceeded to purchase the Federal Telegraph Co. stations and to convince the Shipping Board of the necessity of purchasing the installations on all seagoing vessels of American registry. This transaction was consummated by the Navy's additional purchase of the American Marconi coastal shore stations. Even with Government ownership of practically all the coastal radio stations, congressional approval of the Alexander bill was necessary to prevent the Marconi Co. from building new stations and leasing shipboard equipment once the Government was divested of its wartime authority. However, Daniels believed in the old adage, "possession is nine-tenths of the law."

FAILURE TO ESTABLISH THE MONOPOLY

Following the Armistice the Secretary was successful in reviving hearings on the Alexander bill. These commenced before the House Merchant Marine Committee on 12 December 1918. Daniels stated the Navy's position and followed with a description of the Navy system built up during the war.

[7] "Government Control of Wireless," the Wireless Age, op. cit., February 1917.

[8] Ibid.

His closing statement commended the Navy on its foresightedness in purchasing the Federal and Marconi Co.'s stations, and pleaded for enactment of legislation which would permit the Navy to perpetuate its control. Upon the close of his argument there was heated discussion over these purchases. Congressman Edmonds of Pennsylvania rebuked him severely stating that:

> After this committee refused to bring out a bill to purchase wireless apparatus, you utilized the government's money to purchase this wireless apparatus and took over the commercial systems without the consent of Congress.

He continued, stating that this action had embarked the Nation on a project that should have had congressional approval and accused him of forcing a monopoly of radio communications upon the Government.

Todd, Director of Naval Communications, introduced an amendment to the bill which was calculated to appease the amateurs, and to a large extent did so.

The Marconi Co., aided by the National Wireless Association which had organized powerful support, continued to lead the opposition without change in their line of attack. They were abetted by the midterm congressional elections of 1918 which resulted in a reversal of control of both the Senate and the House. With the Republicans, advocates of private industry, in control, thoughts of Government ownership were but little short of utopian. So vigorous was the opposition that on 16 January 1919 the committee unanimously tabled the bill. It was never reconsidered. Following this action Navy officials, excepting Daniels, shifted their support to further the formation of a strong, American-controlled commercial company.

The Secretary, unwilling to admit defeat, addressed two letters to the President of the U.S. Senate and the Speaker of the House of Representatives. The first one, dated 19 July 1919, transmitted the text of a proposed bill which would authorize the use of radio stations under the control of the Navy Department for commercial purposes.[9] The second letter, dated 24 July 1919, transmitted the recommendation that Congress immediately enact legislation regarding radio communications along the following lines:

> Either by a committee of Congress or by special designated commission, authorize a comprehensive study of the problems in connection with radio within the United States.
>
> Authorize the President to set aside from time to time, by proclamation, certain bands of wave lengths for ship-to-shore work, for shore and aircraft, and for transoceanic service, in accordance with international conventions and demonstrated needs.
>
> Constitute ship-to-shore radio service a government monopoly under the Navy.
>
> Constitute transoceanic and International radio service a government monopoly under the Navy.
>
> Authorize the Navy Department to utilize immediately all Navy radio stations for commercial and press business.
>
> Authorize the Navy and other departments to assist American enterprise in the sale of radio apparatus and the development of American owned radio stations abroad, and especially to authorize the Secretary of the Navy to authorize the use by American companies, under proper conditions, of government-owned patents and improvements, to be paid for either in exchange of patent rights or other suitable ways.[10]

No action was taken on the second letter.

Unswerving to the end of his tenure in office, Daniels' final annual report, which was for fiscal year 1920, stated that the Government should have exclusive control of radio or else make it a monopoly in private hands.

The November 1919 issue of the *Wireless Age* contains an excellent editorial on the radio situation. In substance, this stated that while Secretary Daniels had not abandoned hope of persuading Congress to pass the Alexander bill it was not likely that Congress would yield to any proposal leaning toward Government ownership of this method of communication. It continued, stating that a compromise had been suggested looking to the establishment of

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[9] Annual Report of the Secretary of the Navy, 1919 (Washington, Government Printing Office, 1919), p. 96.

[10] Annual Report of the Secretary of the Navy, 1919, Ibid., pp. 407–412.

an American-controlled company, operating under a Government-authorized monopoly, but that there would be no commitment on the part of the Government until Daniels could be convinced that the legislation desired by the Navy Department could not be obtained. It ended the discussion stating that the solution to the problem appeared to be through private interests under Government control.

ENABLING LEGISLATION

The President, on 11 July 1919, approved the return of the radio stations to their owners on 1 March 1920. Since the Government owned most of the coastal stations, legislation was required to permit the use of these stations for commercial purposes at locations where proper facilities were not provided or until such a time as they could be provided by private interests. Pursuant to the request of the Secretary, dated 19 July 1919, Congress, by Public Resolution, approved 5 June 1920, authorized the use of naval radio stations for a period of 2 years for the transmission and reception of private commercial messages at locations which lacked adequate commercial facilities. This was extended until 30 June 1925 by another Public Resolution approved 14 April 1922. Still further extension until 30 June 1927 was granted by Public Resolution approved 28 February 1925. Prior to the expiration of the last extension, the authority was made permanent by the enactment of Public Law 632, an act for the regulation of radio communications and for other purposes, approved 23 February 1927.

CHAPTER XXVIII

Post-War Research and Development of Radio Communication Equipment

POST-WAR PROBLEMS

The 1916 naval shipbuilding program was to have provided the United States with a fleet which would have been the most modern and strongest in the world.[1] Within a few years following the termination of the war these new ships would require fitting with the most modern radio equipment our engineers could design.

Successful wartime developments such as the mica condenser, the vacuum tube oscillator, the improved vacuum tube detector and amplifier, indicated that vacuum tube transmitters and receivers held forth the greatest promise of success.[2] A decision was made to make no further purchases of spark or arc equipments, but to spend the Navy's research effort towards the development of tube transmitters and to encourage commercial production of standardized types of tubes and tube transmitters suitable for all naval usages. A further decision was made to replace obsolescent apparatus with vacuum tube equipment as rapidly as research and develoment made it available and funds permitted.[3]

Opinion was still divided as to the desirability of having pure continuous wave output for all transmitters. In a very short time the expanded uses of radio forced the conclusion that nothing but this type of emission was satisfactory for a large number of ships operating in close proximity or for shore station transmissions.[4]

POSTWAR RESEARCH AND DEVELOPMENT

Research and development problems included the expansion of the radiofrequency spectrum to provide the additional circuits required for the fleet's strategical and tactical uses of radio; the provision of means for simultaneous reception of several different frequencies with the receivers using the same antenna; the development of higher powered tubes and transmitters; the elimination of the transmission of additional undesired frequencies; and the development of lighter weight equipment for aircraft, and further reduction in aircraft-generated noise and ignition interference.

Research in vacuum tubes was carried on primarily by the General Electric Co. and the Western Electric Co. under Navy insistance, guidance, and financial assistance.

Rapid demobilization limited the work of the Radio Test Shop of the Washington Navy Yard to that of assisting in the design of tube transmitters, the provision of receiving systems, and the development of the

[1] David Saville Muzzey, "A History of Our Country" (Ginn and Co., Boston, 1943), p. 776.

[2] T. Johnson, Jr., "Naval Radio Tube Transmitters," Proceedings of the Institute of Radio Engineers, 1921, vol. 9, no. 5, p. 381.

[3] E. C. Raguet, "Plate-Voltage Supply for Naval Vacuum-Tube Transmitters," Proceedings of The Institute of Radio Engineers, 1930, vol. 18, no. 1, p. 49.

[4] Ibid.

uniwave key for the arc transmitters. Research and development at other navy yards was drastically curtailed, although the Philadephia Yard was able to effect improvements in direction finding apparatus. The Naval Radio Research Laboratory returned to its former work in fundamental research and obtained considerable information concerning the origin of the static caused by the earth's magnetic field. Active research and development was carried on by the Naval Aircraft Radio Laboratory which, still under the direction of Taylor, had been moved from Hampton Roads to the Naval Air Station, Anacostia, D.C. The work of this Laboratory was a continuation of the wartime research and development carried on at Hampton Roads, with additional tasks assigned involving studies in multiple transmission, and reception, and investigations directed toward increasing the width of the usable radiofrequency spectrum.

DISCOVERY OF THE PHENOMENON OF RADAR

In carrying out the last-mentioned task, Taylor, assisted by Mr. L. C. Young, had, by 1922, pushed his experiments to frequencies of 60 megacycles by utilizing superhetrodyne receiving circuits. While working at these frequencies during the summer of that year, Taylor and Young first noted the reflection of signals from vessels passing on the Potomac River and discovered the possibility of obtaining the ranges and bearings of these vessels. This was in fact the discovery of radar, called by Taylor at the time "the detection of enemy ships and aircraft." In September 1922 he addressed a letter to the Bureau of Engineering requesting authority to exploit this discovery stating that the equipment should work during darkness and low visibility as well as on a bright sunny day. At that period of its development, relative movement between the radar equipment and its target was necessary in order that the latter might be detected. The ultimate development of pulse transmission eliminated this requirement. Taylor was not authorized to continue his radar research at that time.[5]

THE NAVY BROADCAST STATION

Public Law Number 264, approved 13 August 1912, required all amateur stations to utilize frequencies higher than 1,500 kc. In the course of their experiments, Taylor and Young contacted numerous amateurs working in the spectrum above this frequency and found that they had a wide circle of listeners in that group. In order to increase the interest of the amateurs, they commenced broadcasting music in 1920, and thus became one of the earliest broadcasting stations. The U.S. Public Health Service became interested in this medium and, with the approval of the Navy Department, commenced broadcasting public health lectures over the laboratory station twice each week.

This broadcast station, with the cooperation of the telephone company, was the first to put the voices of a President, a Chief Justice, a Senator, and a Congressman on the air. President Harding and Chief Justice Taft broadcast during the dedication of the Lincoln Memorial on 30 May 1922. Senator Lodge was the first Senator to broadcast. He gave a short talk intended for a group in his home town of Nahant, Mass. Unfortunately, it could not be restricted to this group, a fact which made the Senator quite indignant.[6] Congressman John L. Cable of Ohio spoke over the station 10 February 1922. The first broadcast of the House of Representatives emanated from the Laboratory. This last important broadcast occurred in the early part of December 1922 when, for the first time in history, a President's message to Congress

[5] A. Hoyt Taylor, "Radio Reminiscences: A Half Century" (U.S. Naval Research Laboratory Report, Washington, 1948), p. 156.

[6] Ibid., pp. 158, 159.

FIGURE 28–1. The Navy's Broadcasting Station NSF, which began broadcasting in 1920, was the first in the Nation's Capital and one of the first in North America. Mr. Leo C. Young, standing, now an Electronics Consultant at the Naval Research Laboratory, and formerly Associate Superintendent, is seen checking the signal modulation through the monitor.

was put on the air. Following this, there were so many special requests that broadcasting began to interfere with research. The broadcasting activity was transferred to Arlington where it was restricted to programs in the public or the Navy's interests.[7]

EARLY POSTWAR VACUUM TUBE TRANSMITTER DEVELOPMENTS[8]

During the war, intensive tube development had been conducted by the General Electric and Western Electric Cos. guided by an advisory committee consisting of representatives of the Army, Navy, Bureau of Standards, General Electric Co., Western Electric Co., Westinghouse Electric and Manufacturing Co., and De Forest Radio Telephone Co. Much was accomplished towards the standardization, increased ruggedness, and longer life of tubes, but little was done to increase their power output. Towards the end of the war, the British developed a 2-kw. vacuum tube transmitter, but the most powerful one developed in this country by that time was 250 watts.

On the termination of the war, the commercial companies refused to continue the development of the tube transmitter be-

[7] Ibid., p. 161.

[8] These transmitters and their normal usages are listed in Appendix M.

cause they considered it of little commercial value. In late 1919 the Bureau of Engineering decided to spend $250,000 for tube transmitters to create incentive for the commercial companies to continue development. Specifications were drawn up for two sets, the Model TC for installation on battleships, and the Model TD for use by air stations in communicating with aircraft. The specifications for the Model TC were based on the British 2-kw. set, with the addition of voice modulation. Its specifications called for an output of 150 watts, while those of the TD called for 750 watts. Twenty of the TC and 15 of the TD were contracted for with the General Electric Co., the low bidder. The total cost of these equipments was approximately $125,000.[9]

In order to provide the Western Electric Co. with incentive to continue development, it was given a contract for 20 sets of Model TB voice modulated equipments. These were to be installed in battleships for the exchange of gunfire control information within a division of such ships.

At this time the Naval Aircraft Radio Laboratory developed the SE 1345, a lightweight transceiver for observation planes.

The performance of all these transmitters was disappointing. Unsolved technical details caused them to give unreliable service. Before the delivery of these equipments was effected, 34 Model TE transmitters, configured to the "S" type submarines which were nearing completion, had been placed under contract with the General Electric Co. It was an improvement over previous models but was not thoroughly satisfactory because space limitations made it inaccessible and required a compactness necessitating the use of insufficiently rugged components. The Model TF had also been placed under contract for equipping converted aircraft tenders. It was similar to the TE, but proved to be more reliable since less stringent requirements for compactness permitted more rugged construction.

[9] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., S. C. Hooper, undated memorandum, SRM 100–286.

POSTWAR VACUUM TUBE IMPROVEMENTS

On 20 January 1920 the Bureau of Engineering held the first of a series of conferences with representatives of various firms in an endeavor to stimulate their interest in the development of higher powered tubes and in the standardization of the characteristics of existent types. At a later conference, held on 31 March, the Bureau representative stated that, in the future, all 50- and 250-watt tubes must be interchangeable with the General Electric Co.'s CG 1144 and CG 916 respectively. It was further recommended that the Western Electric Co. redesign its latest 250-watt tube by increasing its power to 500 watts and making it interchangeable with CG 916. At this same conference a request for the development of a 1,500-watt tube was made, and company representatives advised that future vacuum tube transmitters for the Navy must be designed to include telephonic operation. To encourage the manufacturers, it was stated that 30,000 type SE 1444 receiving tubes would be required within the next 3 years.[10]

This conference marked the turning point in tube development. In early 1921 intensive research was instituted by both the General and Western Electric Cos., which, with the advent of radio broadcasting, saw increased commercial value in tube transmitters.[11] By early 1921 the General Electric Co. had developed a 1-kw tube.[12] By midsummer of the same year it was rumored that the Western Electric Co. engineers had developed a metal tube that could deliver an output of 20 kw.[13] The latter proved to be a water-cooled tube, rated at 5 kw., but which, upon test, gave an output of about 3.5 kw. The General Electric Co. had also developed a similar tube. In late 1921 the Bureau requested

[10] Bureau of Engineering Monthly Report on Radio and Sound, May 1920.

[11] "Radioana," op. cit., SRM 100 286.

[12] Bureau of Engineering Monthly Report on Radio and Sound, April 1921.

[13] Ibid., September 1921.

both companies to attempt to avoid the need of water cooling.[14] A few months later, the General Electric Co. produced a tube which they rated at 5 kw. but which the bureau accepted at 3 kw. and designated CG 1353. The contract price of these tubes was $353 each.[15] In July 1922 the General Electric Co. supplied the Radio Corp. with 20-kw. tubes for installation at its new radio station on Long Island.[16] This was also a water-cooled tube. It was first purchased for naval use in 1924 for converting the 30-kw. spark transmitter at Arlington, Va., into an alternating current vacuum tube set.

NAVY ALTERNATING CURRENT VACUUM TUBE TRANSMITTER DEVELOPMENTS [17]

On 15 May 1921, Senator Borah of Idaho, alarmed at the annually increasing amounts of the naval appropriations bills, proposed an amendment to the current one authorizing the President to invite the chief naval powers to a conference in Washington to discuss ways and means of ending the costly naval competition. This amendment was passed without a dissenting vote and resulted in the Washington Limitation of Arms Agreement.[18] This agreement created the utopian illusion that the world was "safe for democracy" and caused a sharp reduction in naval appropriations.

Because of the drastically reduced naval appropriation, insufficient funds were available to finance the tube transmitter development by commercial companies. The model TL transmitter, designed and developed by naval radio engineers, was finished in 1922 and tested in the winter of 1922–23 on the U.S.S. *Wyoming*. It proved to be very satisfactory. Available spark transmitter power equipment was utilized, thereby reducing the cost of each of these 6-kw. alternating current transmitters by $17,000. Enough of the old spark transmitters were remodeled to provide one Model TL for each battleship. An expected handicap to these equipments was the cost of the short-life tubes. It was decided that four tubes would be purchased for each set as a year's allowance, with the understanding that after these were expended the transmitters would not be used. However, before they were installed in the battleships, the Western Electric Co. was able to provide an improved version of their 5-kw. water-cooled tube. Designated CW 1887, it carried a life guarantee of 1,000 hours.[19] In service some of them lasted as long as 10,000 hours.[20]

At the time the TL was being designed and developed, 100-watt alternating current transmitters for submarines (Model TM) and battleships (Model TO) were being constructed by remodeling spark sets and using tubes as oscillators in lieu of the spark. These Model TM transmitters cost only $400 each and proved far superior to the Model TE. The Model TN, a 6-kw. set, was constructed for shore station use.

Later, a tube transmitter utilizing old spark transmitter components was designed for use on destroyers and light cruisers and the spark gaps at shore stations were replaced by oscillating tube components. Other such self-rectifying transmitters were developed utilizing the 500-cycle supply with modified spark transmitter transformers.[21] These filled the breach prior to the final satisfactory development of reliable tube transmitters permitting the Navy to eliminate most of its spark equipment, and thereby setting an example for the world to emulate.

POSTWAR RECEIVING EQUIPMENT DEVELOPMENT

The immediate postwar work assigned the Radio Test Shop at the Washington Navy

[14] Ibid., December 1921.
[15] Ibid., April 1922.
[16] Ibid., July 1922.
[17] These transmitters and their normal usages are listed in app. M.
[18] Muzzey, op. cit., pp. 775–776.
[19] "Radionana," op. cit.
[20] Bureau of Engineering Monthly Report on Radio and Sound, March 1926.
[21] Raguet, op. cit., p. 50.

Yard was the standardization of shipboard receiving installations with emphasis on increased selectivity so that more circuits could be employed simultaneously. Existing Navy-designed components were assembled and designated Models E, F, and R. The Model E equipment consisted of one low and one medium frequency receiver arranged to permit both to be used simultaneously on one antenna. The Model R, a single receiver installation, was primarily for use in destroyers and other smaller craft. The Model F was also provided with a single receiver but had additional components which permitted it to be used for double reception by using one of the receivers of the Model E installation. Battleships were fitted with both Models E and F; the cruisers and destroyer and other tenders with the Model E. All three models utilized the complicated and temperamental acceptor-rejector circuit copied from that used by the Royal Navy.[22]

None of these equipments met the requirements for submarine installations. In September 1919 the Navy, with the cooperation of the Edison Society, the United States Bureau of Standards, the Hammond Laboratory, and the Marconi Wireless Telegraph Co. of America, commenced experiments to determine the essential factors involved in the transmission to and reception by submerged vessels. Various types of antenna were used, including the conventional flattop, the trailing antenna, and the loop arrangements of Willoughby and Lowell of the Bureau of Standards.[23] It was discovered that the very low frequencies suffered much less attenuation in sea water. The radio station at Nauen, Germany, distant 3,234 miles, transmitting on a frequency of 24 kc., was received by a submerged submarine off New London, Conn. This submarine was fitted with two multiloops located at right angles to each other with the tops of the loops 14 feet below the surface. It was also discovered that, with the submarine at periscope depth, any high-powered station transmitting on a very low frequency could be received at distances up to 3,000 miles. Continued experiments proved that single turn loops were as efficient as multiturn ones and that, at a particular frequency and specific depth of receiving antenna below the surface, the effective range of a signal was directly proportional to the power delivered to the transmitter antenna.[24]

Based upon this information, the Model RA receiving equipment was designed for submarine installations. It utilized standard Navy components and a specially designed loop tuning system, and covered the frequency range 16–1200 kc.

Following the development of the Model RA receiving system, the Radio Test Shop designed Models RB and RC shore station receiving equipments. The Model RB covered the frequency range 10–50 kc. It was made up of available components augmented by a special barrage tuning unit and a new Navy designed receiver, the SE 1530. The barrage tuning unit permitted the use of single wire antenna of about 200 feet in length combined with a loop 8 feet square wound with 48 turns. The new receiver was the first to be designed using an additional circuit, the intermediate, interposed between the primary and secondary circuits. This eliminated the necessity of broadly tuning the secondary circuit.[25] The Model RC was similar and covered the remainder of the usable spectrum up to 2200 kc.

Destroyer operations on the scouting line indicated an increase in circuit requirements over those contemplated when the Model R equipments were installed. Since insufficient space was available for the

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[22] The acceptor-rejector circuit is described in app. M.

[23] Hammond and Purington "Some Foundations of Modern Technology," Proceedings of the Institute of Radio Engineers, vol. 45, no. 9, Sept. 1957, pp. 1194–1195.

[24] Bureau of Engineering Monthly Report of Radio and Sound, July 1920.

[25] U.S. Navy "Manual of Engineering Instructions," Government Printing Office, Washington, 1921, pp. 31–155, 31–157.

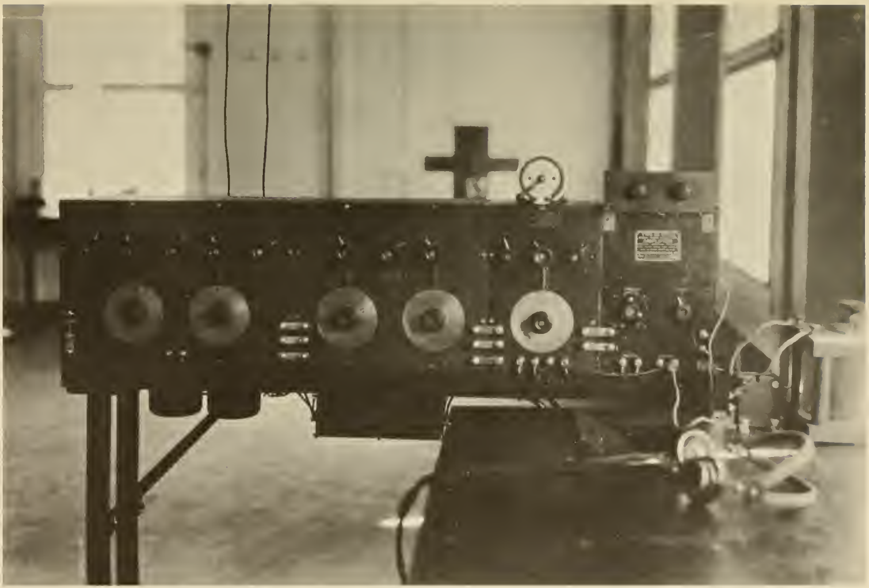

FIGURE 28–2. Model RB receiving equipment consisting of low frequency receiver, SE 1530, barrage tuning unit, SE 1793, radio-audio frequency amplifier, SE 1617, high frequency generator, SE 1603.

Model E the Radio Test Shop designed the Model RD as a replacement. This system utilized two receivers and covered the frequency range 25–1200 kc.

None of these systems can be considered as other than "stop-gaps". The experience gained during the war and the increased knowledge of "radio phenomena" would quickly result in more advanced equipment to be discussed later.

ESTABLISHMENT OF THE NAVAL RESEARCH LABORATORY

In 1916 Congress, acting upon the recommendation of the Naval Consulting Board of the United States, under the chairmanship of Thomas Alva Edison, appropriated funds for the establishment of a naval research laboratory. Construction was immediately started upon the building at Bellevue, D.C., but this was stopped upon the conclusion of the war. Congressional economy held the project in abeyance for several years, but it was eventually completed and established on 1 July 1923. At that time the research and development functions of the Naval Radio Laboratory, the Naval Aircraft Radio Laboratory, and the Radio Test Shop at the Washington Navy Yard were combined and formed the Radio Division of the Naval Research Laboratory. Dr. A. Hoyt Taylor was designated division superintendent and Dr. J. M. Miller assistant superintendent. Miller had been associated with Dr. Austin and was an authority on vacuum tube theory and precision measurements. Austin's health was not good and, to the great regret of all in the Navy who knew him, he had resigned shortly before. His contributions had enriched the knowledge, not only of naval radio, but of the world in general. He continued his studies on high-frequency propagation but devoted more and more of his time to the affairs of the International Scientific Radio Union.

The Radio Division of the U.S. Naval Research Laboratory consisted of the following groups and directors:

Precision measurements	Dr. J. M. Miller
Transmitters	Mr. L. A. Gebhard
Receivers	M. T. McL. Davis
Aircraft radio	Mr. C. B. Mirick
Direction finders	Mr. W. B. Burgess
General research	Mr. L. C. Young

RESEARCH AND DEVELOPMENT OF HIGH FREQUENCY EQUIPMENT

One of the initial tasks assigned the Radio Division of the Laboratory was the continuation of the Naval Aircraft Radio Laboratory investigation of the use of higher frequencies. To accomplish this, a transmitter was developed to cover the frequency range between 1500 and 2500 kc. This transmitter was later modified to an upper limit of almost 3000 kc. Considerable difficulty was experienced in preventing wobbling with the attendant loss of signal when using the heterodyne method of reception. It was discovered that, unless the transmitter and receiver were completely shielded, a slight movement of the operator's hand could produce a change in frequency of as much as 10 kc. Other effects tending to reduce stability were variations in temperature, applied voltage, humidity, and variations resulting from movements of either the transmitting or receiving antenna.[26] Unless something could be developed which would increase frequency stabilization, high-frequency radio would be of little value to the fleet.

At the time the common method of frequency control was by use of a power amplifier circuit which provided a stable frequency control for a small low-powered transmitting tube if adequate shielding was used and a nonfluctuating voltage was applied. The output of this circuit was then applied to the grid of a higher powered amplifier thereby controlling the frequency

[26] Taylor, op. cit., p. 182.

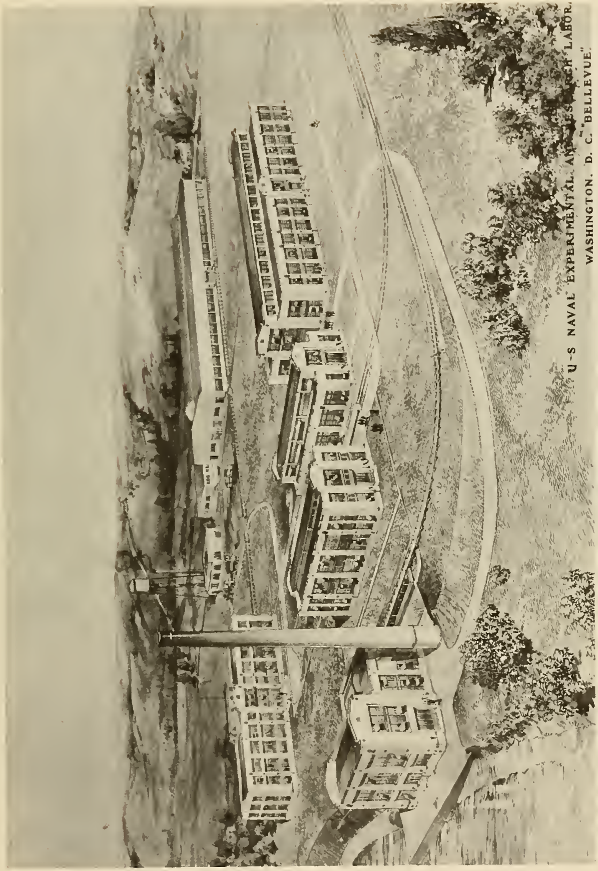

FIGURE 28–3.

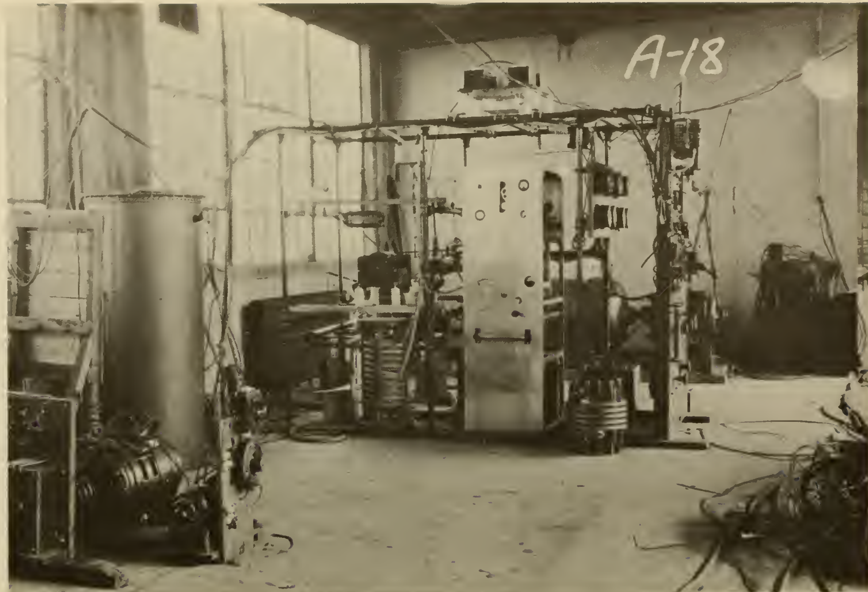

FIGURE 28–4. First high-power, high-frequency quartz crystal-controlled radio transmitter developed by U.S. Naval Research Laboratory in 1924.

Figure 28–5. Radio transmitter designed and built by NRL, 1924.

of the output circuit which was coupled to the antenna. It was discovered that the power amplifier would, if operated on the same frequency as its exciting master oscillator, go off on its own and oscillate on some frequency differing from that desired. Balancing circuits were necessary to control the amplifier.[27]

In continuing with the task, Taylor and Young constructed another transmitter which would operate on a frequency approximating 5700 kc. A master oscillator excited a power amplifier circuit coupled to the antenna and to a counterpoise. The filaments of the tubes and the motor generator, supplying 2,000 volts of direct current, were operated by storage batteries thus reducing voltage fluctuations. Though the stability of this transmitter was good, it was not good enough for fleet communications. It was decided to use piezocrystal control to obtain the necessary stabilization. The consultant services of the two best authorities on quartz crystal, Dr. Karl Van Dyke and Mr. Walter G. Cady, were obtained during the summer of 1924. With their aid the transmitter group designed and built the world's first high-power crystal-controlled transmitter during that year. It delivered 10 kw. to the antenna circuit at a frequency of 4015 kc. and was successfully used on the extremely difficult circuit with London for several years.

Meanwhile, the receiver group designed two new receivers, a low frequency, RE; and the intermediate frequency, RF. These receivers served many years before better ones, meeting naval requirements in the low and intermediate frequency ranges, were designed. But receivers were required for still higher frequencies. Many "soapbox models" were built. These were sufficiently sensitive but too complicated and insufficiently rugged for service use. In 1924 Mr. M. P. Hanson designed the first to meet naval requirements. The receiver group developed and constructed the initial one. It was successfully used by the U.S.S. *Shenandoah,* a dirigible, on her 1924 cruise from Lakehurst, N.J., to the west coast and return. Designated RG, it was the first high-frequency receiver installed in the fleet.[28]

CONTINUED RESEARCH IN THE USE OF HIGHER FREQUENCIES

During the period radio amateurs already numbered in the thousands, and they were becoming increasingly interested in using the higher frequencies. In this they were ably guided by the ranking amateur association, the American Relay League. Although interests of the amateurs lay more in achieving distance and in the number of contacts they could make than in stabilized frequency operation, their cooperation with the Naval Research Laboratory was of great value and led directly to the solution of the behavior of short waves. It had been noticed that frequencies between 2000 and 4000 kc. carried much further during darkness than during daylight and that frequencies between 4000 and 12,000 kc. were better for daylight use. Endeavoring to discover the reasons underlying this, the Laboratory, in conjunction with Mr. John L. Reinartz, owner of an amateur experimental station in the vicinity of Hartford, Conn., commenced experiments. Reinartz, who later was commissioned a commander, USNR, had a continuously variable transmitter covering a wide band of frequencies. The Laboratory had several transmitters, each with two or three different crystal-controlled frequencies, available for simultaneous transmissions. The normal procedure was to establish communication between the two stations on medium frequencies after which Reinartz would gradually raise his frequency while the Laboratory made observations and notified him when his signals ceased to be readable. Usually the signal strength increased until a rather high frequency was reached which

[27] Ibid., p. 183.

[28] Taylor, op. cit., pp. 186–187.

varied from day to day and with the seasons, whereupon the signal strength suddenly dropped to zero. It so happened that Mr. M. J. Lee, later a captain, USNR, operating an amateur station in Orlando, Fla., listened during these operations and noted that when the signals ceased to be received in Washington that he continued to receive them in Orlando. He notified the Laboratory of this, after which his station was added to the experiment. Many tests were conducted, the results indicating the existence of a zone of silence, which varied with the frequency in use. This was the discovery of "skip distance." This phenomenon did not fit in with older wave propagation theories and led to their modification by Taylor and Dr. E. O. Hulbert of the Physical Optics Division of the Research Laboratory.[29]

Considering the "skip distance" phenomena, high-frequency radio could not be used in the fleet in the same manner as the lower frequencies had been utilized. The custom had been to assign units specific frequencies for use day or night, summer or winter. However, the power required for the higher frequencies was so small compared with that for the low and medium frequencies and the signal-to-noise ratio so much more favorable to the higher frequencies that the Navy Department favored shifting to this portion of the frequency spectrum. The fleet was less inclined to do so because of its need for absolute reliability.

FLEET TESTS OF HIGH FREQUENCY RADIO

During early 1925, the Fleet was preparing for a cruise to Australia. It was decided to make an experimental installation in the Fleet flagship, the U.S.S. *Seattle,* where Hooper was again serving as Fleet Radio Officer. He was not convinced of the usefulness of high frequencies at that time. Mr. Frederick Schnell, a naval reserve officer, Traffic Manager of the American Radio Relay League, was ordered to active duty and assigned to assist Hooper in the experiments which were to be conducted during the cruise.

The installation in the *Seattle* consisted of the Laboratory transmitter operating on a frequency of 5700 kc. and an RG receiver. Snell was permitted to install his personal transmitter which covered a wide frequency band. In addition to the one at the Laboratory, RG receivers were installed at San Francisco, Honolulu, and Balboa, C.Z.[30]

The American Relay League made arrangements for the cooperation of amateurs all over the world. For handling official traffic, the Naval Research Laboratory was designated the principal receiving station.[31]

En route from San Francisco to Honolulu numerous tests were conducted. It was discovered that many electrical devices aboard ship emitted radiations that interfered with reception. The rolling and pitching and the vibrations of the ship increased the difficulties in the use of the apparatus which required critical tuning. Despite these conditions, fair results were obtained and these results improved as the operators became more proficient. During the best transmission hours, 2330–0800, zone-plus-5 time, little difficulty was experienced in handling direct communication with Washington, even during the period when the fleet was in Melbourne, nearly 10,000 miles away.[32]

Following these tests, the Commander in Chief recommended the addition of high frequencies to the fleet frequency plan and that shore stations be equipped to transmit to the fleet on frequencies not higher than 9000 kc. The Bureau disregarded the latter and immediately made plans to equip 28 shore stations with transmitters with an upper frequency limit of 18,000 kc. Within a few years the U.S. Fleet was provided with far more reliable equipment than any fleet in the world.[33]

[29] Taylor, op. cit., pp. 138–139.

[30] Ibid., p. 197.

[31] Ibid., p. 198.

[32] Ibid., p. 199.

[33] Ibid., p. 200.

IMPROVEMENT TO THE ARC TRANSMITTER

During the war the Navy had invested a considerable sum in arc transmitters, and economy dictated their continued usage until such time as they became uneconomical in operation. The early high-powered (30 kw. and above) arcs were crude devices compared with present-day standards. The means of keying them was by short circuiting some of the turns of the antenna helix or by changing the capacity of the antenna. Either of these methods caused a change in the emitted frequency. Thus, at the time a signal was being transmitted, the antenna emitted one frequency and, at other times, another, called the spacing or compensating frequency.

The key first provided to operate the changes in antenna inductances or capacities was a crude device known as the "barrel key." It consisted of a wooden lever about 8 feet long pivoted to the top of a large barrel, filled with water. From the end of the lever a heavy wire led down into the barrel where it could be made to contact a heavy metal plate at the bottom. This barrel key was connected across the ground and the insulated lower half of one of the antenna support towers. Messages could be transmitted by it at the rate of about eight words a minute provided a sufficient relay of operators were available for pumping. In 1916 Eaton devised a multicontact key which provided one contact for each turn of the helix. This solved the keying problem insofar as manpower and speed of transmission was concerned but did not eliminate the compensating frequency.[34]

In addition to this compensating frequency the arc also emitted numerous harmonics of both the transmitting and compensating frequencies and, additionally, its tone was quite mushy. With the reactivation of amateur activities in 1919 and the advent of broadcasting in 1921, considerable criticism was justly leveled at the Navy because of the interferences they caused. A research and development problem was established to devise means of eliminating the compensating frequency, the harmonics, and of decreasing the mush.

The Federal Telegraph Co., Gunner Kenny in the U.S.S. *Ohio,* Cohen and Eaton at the Radio Test Shop, all worked on the development of a uniwave key. Cohen developed one which cut resistance in and out of an absorbing circuit but it was too critical to be of practical use. Eaton later devised a satisfactory keying system which retained the absorbing circuit but utilized a bank of noninductive resistance units between the transmitter and the antenna and absorbing circuit. The absorbing circuit was connected to the arc through a transmitting key resistor. When the keying contact was open the absorbing circuit prevented the antenna from radiating, thus eliminating the compensating frequency.[35]

To eliminate harmonics two methods were attempted. One was the use of a high pass filter in shunt with the arc, the other was to couple the arc to a rejector circuit in series with the antenna. The first method, devised by Radio Aid Buttner, proved the simpler, while the second, designed by Radio Aid Hallborg, gave more efficient operation. On 11 February 1922 a conference was held in the Bureau to plan further steps for the elimination of harmonics and reduction of mush. It was recommended that further experiments be conducted on the two systems. During these tests it was discovered that the Buttner circuit reduced the efficiency to an unsatisfactory extent and this necessitated the adoption of the Hallborg method despite its being more difficult to tune. Interference created by the arc transmitter was successfully eliminated by the adoption and installation of this circuit.

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[34] "Radioana," op. cit., Clark, "Radio in War and Peace," pp. 275–303.

[35] Bureau of Engineering Monthly Report on Radio and Sound, November 1920.

THE U.S.S. *OHIO*—RADIO EXPERIMENTAL SHIP

In August 1919 the obsolete U.S.S. *Ohio* was assigned to the Bureau of Engineering as an experimental ship to facilitate the development and service testing of new radio equipment and installations. This was done to eliminate the annoyances occasioned by conducting experiments on ships actually engaged in training exercises.

The *Ohio* was degunned and refitted for her new role at the Navy Yard, Portsmouth, Va. The original radio room was left unchanged to handle the ship's normal radio traffic. Two additional large radio rooms were located below decks. One was fitted with the transmitters which included a 20-kw. arc, a 5-kw. arc, and a 5-kw. spark, and a motor buzzer set. The other was equipped with models E, F, and G receiving systems. Two large antenna trunks, one of steel, 3 feet in diameter, the other of copper, 30 inches in diameter, were installed between the main deck and the experimental transmitter room. Special topmasts which could be varied in height in increments of 5 feet were added to the cage masts. These provided a maximum height of 180 feet above the waterline.[36]

The refitting was completed in April 1920 and the *Ohio* was stationed at Annapolis under the command of Capt. John F. Halligan, USN, the commanding officer of the Naval Experimental Station. Lt. H. F. Mennerati, USN, a most capable, practical radio engineer, was the executive officer, first lieutenant and radio officer.

The Bureau immediately assigned numerous tasks to the ship among which included:

Service tests of new radio equipment;

Improvement of the standard radio installation in battleships to provide maximum simultaneous transmission and reception;

Determination of minimum size and type of material for radio trunks required for below-deck installation of 20-kw arc transmitter;

Measurements of antenna constants under all conditions and a study of their natural variations;

Measurements of antenna and trunk potentials for arc and spark transmitters at various powers;

Comparative tests of arc transmitter keying methods;

Determination of stresses in shipboard antennas under service conditions;

Comparison of the CW 936 with later radiotelephone sets as to interference on the same and nearby ships;

Experiments with acceptor-rejector circuits;

Experiments with loop antennas for reception of short range transmissions; and

Determination of the absorption, shadow, and reradiation effects of cage masts.[37]

This was a monumental assignment for a ship with such a drastically reduced crew that even the mess attendants were pressed into service to assist in conducting the experiments. Mennerati did much to increase practical knowledge concerning shipboard radio installations especially those involving antenna constants, arc transmitter keying, improved battleship installations, and the effects of cage masts and other closed circuits. He could not completely solve all the assigned problems due to interferences beyond his control.[38]

USE OF REMOTE RADIO CONTROL OF SURFACE VESSELS

Following the war bitter arguments arose relative to the effect of aviation upon naval warfare. Many considered the day of the capital ship at an end. Aviation enthusiasts claimed that one bomb would sink a battleship. The Navy was willing and eager to support aviation but it desired that naval aviation be an integral part of the service, and that heavy ships not be scrapped without positive proof of the effects of bombings. Tests were arranged using captured German vessels and the obsolete U.S.S. *Iowa*. The first tests were for the purpose of determining accuracy; therefore the ships used as targets were anchored and concrete bombs were used.

[36] Bureau of Engineering Monthly Report on Radio and Sound, May 1920.

[37] Ibid.

[38] Ibid., 1920–1921.

FIGURE 28–6. Lt. Jennings B. Dow, USN, at the radio control of USS *Utah,* maneuvering the radio-controlled battleship *Iowa.*

In the final test, the *Iowa* was to be utilized as a maneuvered target and live bombs were to be used. Mr. John Hays Hammond, Jr., graciously consented to the use of his radio control patents for this purpose. Equipment was designed, built, and installed in the *Iowa* and *Ohio* by the General Electric Co. assisted by naval radio engineers. The *Ohio* was used as the control ship. On 21 June 1921 over 100 radio control signals were transmitted by the *Ohio,* from a distance of 8,000 yards, all of which functioned. At 0900, 22 June, the crew was removed from the *Iowa.* At 0917 the target was placed under radio control but 3 minutes later the machinery in the engine and fire rooms ceased functioning. The crew returned and discovered trouble in the automatic boiler feed-water regulator. Shortly thereafter the arrival of the bombing aircraft was reported, necessitating the removal of the crew before the regulator could be properly adjusted. During the bombing 88 radio control signals were made, all of which functioned. Two direct hits were made on the forecastle of the *Iowa* which did exceedingly little damage.[39] Battleships were not yet doomed.

The use of the *Ohio* for experimental purposes was curtailed by its use as a con-

[39] Ibid., July 1921.

trol ship but as soon as this duty was completed Mennerati resumed his assigned tasks. Unfortunately this work was terminated by the scrapping of the *Ohio* as a result of the Washington Disarmament Conference. She was placed out of commission early in 1922 and thereafter service tests and experiments were necessarily conducted on operating ships.

UNDERWATER PILOT CABLE

The loss of time of transports and cargo carriers caused by lack of visibility was one of the serious problems encountered during World War I. At the end of hostilities direction finder stations were being hastily erected at the entrances to important ports. These would suffice to get ships to the entrances but were of only slight value in navigating the restricted waters of the various ports.

Radio Aid E. C. Hanson developed and patented an audio-piloting cable. He authorized the Navy to utilize this patent without cost. Late in 1919 a system was laid in Ambrose Channel, at the entrance to the harbor of the city of New York, from Fort Hamilton, N.Y., out to the center of the channel, using lead and armored cable. From this point rubber-covered cable was laid and anchored in the center of the channel to its seaward beginning and thence to a point near the Ambrose Channel Lighthouse. This cable, the total length of which was approximately 14 miles, was energized by a 1-kw., 500-cycle generator. The flow of current in it was interrupted by means of an automatic transmitter which sent the code equivalent of "NAVY."[40]

The receiving equipment required by a ship utilizing the cable consisted of two coils wound with 400 turns of No. 24 copper magnet wire, each having the same values of resistance and inductance.[41] These were placed over the side of the ship at about the waterline where they picked up the magnetic field created about the rubber-covered cable when it was energized. Each of these coils was connected to a separate vacuum tube amplifier. By means of a two-way switch the operator merely listened to first one coil and then the other and by determination of a signal strength estimated his location relative to the cable.

Official demonstrations were held from 6 to 9 October aboard the U.S.S. *Semmes,* which used the cable entirely for controlling its position. The system was explained to the officials of various shipping interests, pilots associations, and other interested parties. These tests proved its possibilities as a means of permitting navigation in restricted waters during periods of low visibility.

Following the tests the project was transferred to the Department of Commerce, which by law was responsible for navigational aids. That Department evinced no interest in the project. The cable was removed from the channel and installed parallel to a landing strip and out into the Anacostia River at the U.S. Naval Air Station, Anacostia, D.C., for the purpose of testing it as an aircraft approach system.

This did not prove too successful because it required large loops on each wing of a plane and even with those the signals could not be received at altitudes much in excess of 200 feet. It was the first experiment with an aircraft instrument landing system.[42]

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[40] Bureau of Engineering Monthly Report of Radio and Sound, November 1919.

[41] The Wireless Age, October 1920, p. 8.

[42] S. C. Hooper "History of Radio, Radar and Sound in the U.S. Navy," Office of Naval History, Washington, D.C., recordings 48R115–123.

CHAPTER XXIX

Remote Radio Control

EARLY ENDEAVORS TO CONTROL OBJECTS BY RADIO

In 1887, Englishmen E. Wilson and C. J. Evans were successful in controlling slow-moving boats by radio on the Thames River. In 1900 they were granted U.S. Patent No. 663,400 on their method. Nikola Tesla worked upon a similar control idea and, in 1898, built a working model which he successfully demonstrated at the Auditorium in Chicago. He was granted U.S. Patent No. 613,809 on this in 1898. However, Bradley A. Fiske, a U.S. naval officer, had evolved a similar idea a little earlier and he was granted U.S. Patent Nos. 660,155 and 660,156, both underlying Tesla's.[1]

In 1905 the International Wireless Telegraph Construction Co. contracted with the Quintard Iron Works of Boston for the construction of four radio-controlled torpedoes designed by their chief engineer, Prof. Harry Shoemaker. They consisted of a standard naval torpedo rigidly suspended from a surface float which supported the receiving antenna. The U.S. Government did not consider them of military value, and that archsalesman of radio apparatus, John Firth, was successful in selling them to the Japanese Navy.[2]

Following this, unsuccessful efforts were made by various individuals in several countries to perfect a radio-controlled torpedo.

DEVELOPMENTS BY JOHN HAYS HAMMOND, JR.

John Hays Hammond, Jr., became interested in radio control, and his preliminary work from 1910 to 1912 led to the development of the "automatic course stabilization principle" and a satisfactory method for "security of control." [3]

The Coast Artillery Corps of the U.S. Army had been seeking a torpedo that could be controlled from a shore site. In late 1912 the Chief of that Corps, Brig. Gen. E. M. Weaver, USA, and his assistant, Col. R. P. Davis, USA, witnessed Hammond's successful radio control of a launch at speeds up to 33 knots. Weaver was sufficiently impressed to detail Capt. F. J. Behr as an observer to the Hammond Laboratory that had been established earlier in that year. Twelve technical sergeants were detailed to operate and maintain Coast Artillery apparatus provided to aid the developments along proper military lines.[4]

In 1912 the Sperry Gyroscope Co., with the aid of the Navy, developed a reliable motor-driven gyrocompass with remote repeaters. This system was thoroughly tested on the U.S.S. *Utah,* approved for service use, and adopted as a standard installation for naval vessels. Hammond engineered a

[1] J. H. Hammond, Jr., and E. S. Purington, "A History of Some Foundations of Modern Radio-Electronic Technology," Proceedings, Institute of Radio Engineers, vol. 45, September 1957, p. 1191.

[2] Ibid.

[3] Ibid., p. 1192.

[4] Ibid., p. 1192.

modification of this system so that a repeater could control a steering engine. This permitted the simple application of radio control by fitting the gyroscope with solenoids to step its setting to the left or right a fixed number of degrees in response to each control signal. The direction of change was controlled by the timing pattern of a few dashes acting upon the primary control relay.[5] The first sustained use of the automatic pilot, commonly called "Metal Mike," was demonstrated on 25 March 1914 when the yacht *Natalia* was controlled by it throughout a 60-mile run. Although the acceptance of this system as a steering aid for surface vessels and submarines was advocated by Hammond, the Navy was reluctant to utilize it. This stemmed from the fear that automatic steering might increase the chances of collision due to the possibility that too much faith might be placed on it and also that it might not be possible to disengage it and resort to normal methods when necessary. In a conference held on 9 February 1916, Hammond succeeded in allaying these fears.[6]

The use of the motor-driven gyroscope simplified and contributed greatly to the security of control by greatly reducing the number of required control signals, and by enhancing the difficulty of anlaysis. The control signals could be changed during a specific run and dummy signals could be transmitted. It was also possible to lock the gyro setting and utilize conventional stabilized course control at will, or, as an alternative, the object could be converted into a target-seeking missile if radio countermeasures were employed against it. Suitable timing patterns at varying frequencies could be employed to increase the difficulty of immediate analysis and ready duplication by an enemy.[7]

Actually, the Hammond system used dual-channel transmission, a type originally proposed and patented by Tesla. In the earlier Tesla system two receivers, with rectifying detectors, operated two corresponding relays that had to be closed simultaneously to actuate a third one which controlled the pattern analyzing and distributing system. In the Hammond system used on the *Natalia,* transmission over the dual channels was rapidly sequential from the same transmitter. To produce a control dash first, a half-dash was transmitted on one frequency followed by the second half-dash on a widely separated one. The receiver tuned to the frequency of the first transmission automatically was returned to the frequency for the second transmission, while the first half-dash was held in storage. If the second half-dash was received within a certain established time limit, the first half-dash was released from storage and actuated the controlling relay. The system restored to normal after expiration of the established time limit, or upon reception of the complete dash, and awaited further signals. This was the first use of both time and frequency diversity for security purposes. Other timing patterns controlled engine speed, searchlight shutter opening, and the laying of mines. It was the function of the analyzing and distributing system to identify and channel these signals to the proper mechanism. The target-seeking feature of the system provided directional control by searchlight beam or radio interference. Two selenium cells mounted on the foremast operated differentially until the weapon carrier was headed into a light beam. The radio countermeasures control used cross loops, both of which were tuned to the wavelength necessary for interference, Until the interfering signal was dead ahead, the signal was stronger in one of the loops, activating that portion of the circuit necessary to move the rudder to bring the weapon-carrier course into the direction of the signal.[8]

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[5] Ibid., p. 1192.

[6] Letter, dated 26 Feb. 1958, from E. S. Purington, Vice President of Hammond Research Corp.

[7] Hammond & Purington, op. cit., p. 1193.

[8] Ibid., p. 1193.

TEST OF HAMMOND REMOTE CONTROL SYSTEM

On 6 October 1914 tests of the Hammond system were made in conjunction with the U.S. Navy. The U.S.S. *Dolphin,* fitted with the best available radio equipment and interfering sequentially on frequencies of 1,000, 600, 400, and 300 kc., was not able to exercise control over a surface weapon carrier using frequency modulation on frequencies of 118 and 1,000 kc. until it worked within 250 feet of her. From this distance to the *Dolphin* it could have been operated with locked gyro or it could have been converted to target seeking. Following further demonstrations on 16 and 24 November the Government considered the project ready for development as a service weapon.[9]

LEGISLATION FOR THE PURCHASE OF THE HAMMOND SYSTEM

Plans for development of the project were submitted to Congress in 1915, too late for consideration.[10] On 23 March 1916 Hammond presented a proposal to the War Department which, in turn, presented it to the 64th Congress. A subcommittee of the House Committee on Appropriations in its hearings on fortifications appropriations inquired fully into the following aspects of the system: Interference with the control system by enemy countermeasures; effect of hostile gunfire; limits of operational range; and ability to control the weapon carrier by aircraft.[11]

The fortifications appropriation bill for the fiscal year of 1917, approved 6 July 1916, appropriated $750,000 for the procurement and exclusive rights of John Hays Hammond, Jr., and the Radio Engineering Co.[12] of New York, to their discoveries and inventions pertaining to the radio dynamic control of waterborne carriers of high explosives. Of this sum, the bill authorized the expenditure of $30,000 for conducting a demonstration of the application of the system to the control of torpedoes before a board to be appointed by the President, consisting of six officers, three each from the Army and Navy. The expenditure of the remainder was contingent upon the favorable recommendation of this board. The bill further stipulated that, in the event of the entrance by the Government into a contract with the above parties, the Commissioner of Patents would title the United States with any patents applied for by the above and granted in connection with such a system. Such patents, when titled to the United States, were to be held secure in the Patent Office secret archives. The same bill appropriated $417,000 for the procurement and installation of one radiodynamic torpedo unit. The expenditure of this sum was contingent upon the execution of the contract for the procurement of the exclusive rights in the system.

On 25 August 1916, by direction of the President, the Board was convened with the following membership:

Maj. Gen. Leonard Wood, USA,
Cap. John A. Hoogewerff, USN,
Com. David W. Todd, USN,
Lt. Col. George O. Squier, Signal Corps, USA,
Lt. Joseph V. Ogan, USN,
Capt. F. Q. C. Gardner Coast Artillery Corps, USA.[13]

Unfortunately, the act of 6 July did not define the type of torpedo to be controlled and this later became a matter of considerable importance to Hammond, the members of the Board, and the two services. The details of the controversies that ensued are beyond the scope of this work and will be dealt with only as they affected the development of a radio-control system.

[9] Ibid., p. 1194.

[10] Ibid., p. 1194.

[11] Statement of John Hays Hammond, Jr., to the Secretary of War dated 12 Aug. 1921, pp. 5–6, files, Hammond Laboratories, Gloucester, Mass.

[12] This was Hammond's firm.

[13] War Department Special Order No. 199, dated 25 Aug. 1916, files, Hammond Laboratories, Gloucester, Mass.

DEMONSTRATIONS OF THE HAMMOND SYSTEM

On 24 August 1917 Hammond appeared before the Board and read a prepared statement which is appended to the minutes of the Board of that date. In this paper he stated that he proposed to demonstrate his system before the Board by having an operator in an airplane control the movements of a surface boat in such a manner as to cause it to strike moving targets. Both the airplane and the boat were to be offshore a maximum of 15 miles. He closed this statement by expressing the opinion that the satisfactory conclusion of such a demonstration should satisfy the Board and result in their submitting a favorable report.

The Board considered this statement at the same meeting but concluded that, in addition to any demonstration Hammond might desire to make, it desired the following:

(1) A demonstration of the maximum range a surface boat could be accurately controlled by a station located on shore; and,

(2) A demonstration of the accurate control of a surface boat engaged in striking a rapidly moving target by exercising the control from an aircraft in flight.[14]

After a year of preparation, Hammond notified the Board that he was ready to conduct the required demonstration. During that time Lt. Comdr. George B. Wright, USN, relieved Ogan, and Maj. Eugene Reybold, Coast Artillery Corps, USA, relieved Gardner as members of the Board.[15]

On 23 August 1918 the Board convened at Fort Monroe, Va., to witness the demonstration. The minutes of the meeting of that date state that the demonstration was conducted to indicate:

(1) the practicability of controlling an unmanned moving vessel either from a shore station or an airplane in flight by radio adjustments of the steering and motor speed functions and, additionally, the control of mine-dropping apparatus by either the shore station or aircraft; and,

(2) the ability to control totally submerged vessels by submarine sound signals.

Following successful demonstration of the above and lengthy discussion relative to the adaptation of the system to controlling submerged and aerial torpedoes, the Board adjourned without advising Hammond of its findings.[16]

ACTION OF THE JOINT TORPEDO BOARD

Several meetings of the Joint Torpedo Board were later held in Washington, and Hammond was requested to attend one held on 31 October. At this meeting he was advised that the Board could not make a favorable finding as the result of the demonstration and indicated a requirement for a demonstration of the control of a completely submerged torpedo. The minutes of the meeting further state that there was a short informal conference with Hammond, but they do not indicate the tenor of the discussion.[17] Hammond later wrote

[14] Minutes of the Joint Torpedo Board dated 24 Aug. 1917, files, Hammond Laboratories, Gloucester, Mass.

[15] Orders of the Chief of the Bureau of Navigation (N–31/BR) dated prior 23 Aug. 1918; War Department message dated 21 Aug. 1918.

[16] Minutes of the meeting of the Joint Torpedo Board, 23 Aug. 1918, files, Hammond Laboratories, Gloucester, Mass.

[17] Excerpts from the minutes of the meeting of the Joint Torpedo Board, 31 Oct. 1918:

"The Act approved July 6, 1916, providing for fortifications and other works of defense, contained in part the following provisions:

"For the procurement of the exclusive rights of John Hays Hammond, Jr., and the Radio Engineering Company of New York (Inc.) to their discoveries and inventions in the art of control by radiodynamic energy of the movement of waterbourne carriers of high explosives, etc. The Act also provided that the funds appropriated for the procurement of the rights above mentioned should not be paid "except upon the approval by the President of a report of a board of three Army and three Navy officers to be appointed by him which report shall be favorable to the acquisition of such rights, such report to be made after a demonstration of the application of the said system to the control of torpedoes.

"The first of the foregoing quotations assumes that he immediately protested the findings and stated that he felt the Board was not dealing fairly with him; that he had successfully demonstrated what was thoroughly agreed upon; and that the Board was apparently attempting to extract more than had been expected. In the same statement, he wrote that notwithstanding its findings he would continue to improve the system at his expense, feeling that, in all fairness Government officials would provide him assistance in meeting their demands.[18]

AMENDED LEGISLATION FOR PURCHASE OF HAMMOND SYSTEM

From time to time thereafter, Hammond conferred with the Secretary of War and in one of these meetings he explained that he had expended over $400,000 in the demonstrations and was unable to continue further development at his own expense. The Secretary agreed to endeavor to obtain an amendment to the act of 6 July and, on 20 January 1919, addressed a letter to the chairman of the House Appropriations Committee requesting that the $417,000 appropriated for the procurement and installation of one radiodynamic torpedo unit be changed to cover the demonstration of the radiodynamic control of torpedoes and underwater carriers and for installing one torpedo unit.[19]

Hearings on this proposed amendment were held before the Fortification Committee and, following its favorable recommendation, section 7 of the fortifications appropriation bill for the fiscal year 1920

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the existence of discoveries and inventions for controlling by radiodynamic energy the movement of water-bourne carriers of high explosives. The second quotation prescribes a demonstration of the application of these discoveries and inventions to the control of torpedoes. It is the opinion of the present Joint Board that a distinction should be made between the control of water-bourne carriers of high explosives and the control of torpedoes.

"There have been no demonstrations of the application of the said system to the control of torpedoes. There have been demonstrations of the control of surface craft by radiodynamic energy, which demonstrations have convinced the Board of the practicability of this method of control. There have also been demonstrations of the possibility of applying radiosonic control to a completely submerged carrier. There have also been submitted to the Board claims as to the possibility of radiodynamic control of a carrier submerged except for an air-intake pipe. The Board has grave doubts as to the practicability of successfully developing these claims. Before taking final action favorable to the acquisition of the rights to the discoveries and inventions under consideration, it is the opinion of the Board that an actual and satisfactory demonstration of the practicability of such claims should be made.

"If it is claimed that the demonstration of the application of the said system to the control of torpedoes is covered by the demonstration of the application of the system to the control of surface carriers, such claim, while contravening the views of the Board as to the demonstration, required by the Act, would, if allowed, be of no value to the inventor, since in such case the Board would feel constrained to render an unfavorable report as to the acquisition of the rights in question. This action would be based upon the limited value of such means of control. The General Board of the Navy in its letter to the Secretary of the Navy of May 3, 1918 sets forth the reasons why a surface boat controlled by either radio or compressional waves is not suitable for strictly Naval use. Certain of these objections, too, apply equally to the use of this weapon for Coast defense.

"The limited use which might be made of such boats as indicated in paragraph 18 of the letter of the General Board is not sufficient in the opinion of this Board to warrant the acquisition of the rights at the price specified in the Act of Congress.

"The Board does not consider that it is a part of its province to specify or to suggest to Mr. Hammond the details of the demonstration which would be regarded by it as satisfactory and warrant a favorable report as to the acquisition of the rights in question. It may be stated, however, that the scope of such a demonstration must be such as to establish the validity of the claims made by Mr. Hammond as to the practicability of applications of his method.

"So far, Mr. Hammond has not demonstrated to the satisfaction of this Board that he will be able to make successful application of his methods to the effective underwater attack of Naval craft; but the Board is of the belief that it may be possible to accomplish this in the future. Such a development would have a decided tactical value" (minutes of the meeting of the Joint Board, 31 Oct. 1918).

[18] Statement of John Hays Hammond, Jr., to the Secretary of War dated 12 Aug. 1921, p. 18, files, Hammond Laboratories, Gloucester, Mass.

[19] Ibid., pp. 19–20.

amended the 1917 appropriation bill as requested. Additionally, this legislation removed responsibility from the Board established by the 1916 act and placed it in the hands of the Secretary of War. The Board was continued in an advisory capacity.

THE COAST ARTILLERY WEAPON PROJECT ABANDONED

Hammond immediately proceeded with the work on the assumption that the War Department would bear the burden of the expenses. The size of his laboratory was increased to provide facilities for the Army personnel ordered to assist in the project. He requested funds to pay for this and other expenditures, including the salaries of his engineers, but found the War Department unwilling to utilize the appropriated funds until they were satisfied by reasonable guarantee of the successful completion of the unit required by the amended legislation.[20]

On 29 July 1921 the officer in charge of the project reported to the Chief of Coast Artillery that, in his opinion, the tactical value of the weapon had been almost entirely lost in view of the recent aircraft bombing tests held off the Virginia Capes.[21] On the following day the Chief of the Coast Artillery recommended discontinuance of the project for the above reason, stating that his remarks should not be construed as having any bearing on the desirability of further work looking to the development of the control of completely submerged torpedoes by radiodynamic energy.[22]

The lengthy statement submitted by Hammond to the Secretary of War on 12 August 1921 summed up the entire project from its conception to the date of the recommendation of the Chief of the Coast Artillery, and in conclusion stated:

> . . . I submit that the abandonment of the project as a whole at this time would nullify all of my efforts for the past ten years, would penalize me and my corporation for the good faith and confidence placed in the government and the intensive labors to produce something of value to and desired by the government would cause a serious financial loss of over $450,000 to me and my corporation, would tend to deprive me of the right to secure my award in accordance with the acts of Congress and the written promises of the government, would be tantamount to a breach of contract, and, in my opinion, would not subserve the best interest of the country.[23]

RESEARCH IN RADIO CONTROL OF THE STANDARD NAVY TORPEDO

In 1918 the Navy conducted experiments at New London, Conn., to determine the factors concerned with radio reception in submerged craft. In these experiments the U.S. Bureau of Standards, the Hammond Laboratory, and the Marconi Wireless Telegraph Co. of America cooperated. Tests of a submerged submarine with a 300-foot rubber-covered and sealed antenna supported at a depth of 6 feet proved that radio control of a submerged torpedo by a plane utilizing an 85-watt continuous-wave transmitter on 188-kc. frequency was entirely feasible at that depth.[24] As a result of these experiments, the Board recommended that the proper naval weapon using radio control be a standard naval torpedo with an added midsection to house the radio-control equipment. A decision was made to discontinue the development of a surface- or snorkel-type torpedo and to concentrate on the development of the radio-controlled submerged naval torpedo.[25]

[20] Ibid., pp. 24–29.

[21] Ibid., p. 29. Hammond's radio-control system had been utilized to control the bombing targets.

[22] Letter, dated 30 July 1921, from Chief of Coast Artillery, USA, to the Secretary of War.

[23] Statement of John Hays Hammond, Jr., to the Secretary of War, dated 12 August 1921, p. 34.

[24] Hammond and Purington, op. cit., p. 1195.

[25] In retrospect it is easy to criticize this decision, but the reader is reminded that, at that time, control of the air was considered one of the major requirements of successful naval operations in order

In 1918 the Navy General Board concluded that a radio-controlled underwater torpedo would have decided tactical value and would tend to increase the nervous tension of an enemy. In compliance with this guidance, the Chief of the Bureau of Ordnance directed the Naval Torpedo Station, Newport, R.I., to assist Hammond as much as was practicable in the development of a radio-controlled standard naval torpedo. The letter stipulated that the torpedo should be controlled while running at a depth of 10 feet without the antenna projecting above the water. It also required that the torpedo should be capable of being launched from an above-water tube with the antenna either contained in the torpedo or ejected or reeled out after launching.[26] Based upon this directive, work was commenced at Newport with the direct costs being defrayed by the Bureau of Ordnance.

In late December 1921 the Chief of the Bureau of Ordnance advised the Assistant Secretary of the Navy that, as soon as Hammond demonstrated the radio control of a naval torpedo running throughout a distance of 9,000 yards at a depth of 12 feet, he would recommend the question of payment of Hammond be decided.[27]

Following the withdrawal of Army support the Navy sought a reapportionment of the remainder of the funds contained in the appropriation for fiscal year 1920, and in 1925 Congress approved such action.[28]

Work continued on the project and in midsummer of 1925, a successful run at an approximate depth of 6 feet was made with the controlling station about 3 miles distant.[29] However, 5 years were to elapse before the final tests, meeting the requirements established in December 1921, were completed during the winter of 1930-'31. On 30 July 1932 the Navy concluded the contract provisions of the act of 6 July 1916, and acquired the rights, for radiodynamic purposes, in over 100 Hammond patents.[30]

EARLY NAVY FLYING BOMB RESEARCH, DEVELOPMENT, AND EXPERIMENTATION

In early 1915 Dr. Peter Cooper Hewitt became interested in the development of a pilotless flying bomb and consulted Mr. Elmer A. Sperry, famed for his gyro-stabilization work, as to the feasibility of such an idea. It was agreed that Hewitt would provide $3,000 and the Sperry Co. would endeavor to develop the necessary gyro-stabilization equipment. The project quickly absorbed the $3,000 plus additional funds supplied by the Sperry Co., after which an appeal was made to the military services to continue the project. The possibilities of the project were favorably considered by the Naval Consulting Board which had been established on 7 October 1915 to advise the Secretary on scientific and technical matters. Both Hewitt and Sperry were members of the Aeronautic Committee of this Board.[31] The Chief of the Bureau of Ordnance, Rear Adm. Ralph

to insure that the naval aviators could act as the "eyes of the fleet." Spotting the "fall of shot" was one of their primary duties and controlling a submerged torpedo did not vary too greatly from this. Not only did submarines and destroyers carry these weapons, but also some of the older battleships. The torpedo had not completely become a weapon of stealth and opportunity, but was looked upon as a means of disrupting an enemy battleline. Nevertheless, as we look back upon naval history we do not find that a single radio-directed submerged torpedo was ever used to sink a ship but that on several occasions such surface-type missiles have been successfully utilized.

[26] Letter, dated 21 Nov. 1918, from Chief of the Bureau of Ordnance to the inspector of ordnance in charge, U.S. Naval Torpedo Station, Newport, R.I.

[27] Letter, dated 7 Dec. 1921, from Chief of the Bureau of Ordnance to the Assistant Secretary of the Navy.

[28] Hammond and Purington, op. cit., p. 1195.

[29] Bulletin of Ordnance Information, August 1925, p. 20.

[30] Hammond and Purington, op. cit., p. 1196.

[31] Lloyd N. Scott, "Naval Consulting Board of the United States," 1920.

Earle, USN, directed Lt. T. S. Wilkinson, USN, to proceed to the Sperry Co. field station at Amityville, Long Island, to observe and report on tests to be conducted there.

In his report, Wilkinson stated that the tests were twice delayed by engine troubles but were eventually held on 12 September. The report contains a description of the stabilization and coursekeeping devices installed in the seaplane which also carried a pilot since it was not desired that the plane and its equipment be expended. Although the weather conditions were unfavorable, the plane was taken from the water, placed under automatic control, climbed to the preset altitude and maintained this altitude until the end of the preset time, following which it dived sharply and the pilot took control and made a safe landing. Wilkinson concluded that the bomb could not be perfected to the necessary degree of accuracy required for hitting a moving target at sea and recommended that the development be sponsored by the Army as that service might find it useful against large military targets.[32]

Wilkinson's report notwithstanding, the Naval Consulting Board recommended that the Navy conduct experimental work on automatically controlled aircraft, carrying high explosives, capable of being initially directed and, thereafter, automatically managed.[33] A board consisting of Capt. W. S. Smith, USN, senior member; Naval Constructor J. C. Hunsacker and Lts. G. De Chevalier, W. G. Childs, and T. S. Wilkinson, USN, was convened to determine further action to be taken by the Navy.[34] This Board recommended that the Navy participate in the project.[35] On 22 May 1917 the Secretary approved the recommendation of the Naval Consulting Board.[36] He directed the Bureau of Ordnance to allocate $100,000 and the Bureaus of Construction and Repair and Steam Engineering each to allocate $50,000 in support of the project.

A contract was negotiated with the Sperry Co. for experimentation with the ultimate aim of developing a weapon. The Navy agreed to provide five N-9 seaplanes with landplane landing equipment and to purchase six sets of Sperry automatic control equipment. The Sperry Co. was to provide testing grounds, hangar, and such technical staff as the Consulting Board might direct. On 15 June Comdr. B. B. McCormick, USN, was ordered to the Sperry plant, as Naval Inspector of Ordnance, to provide naval supervision over the project. Upon his arrival active work was initiated.

The possibility of controlling the flying bomb by radio was probably discussed by the Naval Consulting Board and by the officiers of the Bureau of Ordance during conferences preceding the Secretary's decision. In one of his first periodic reports, McCormick stated that the development of the project consisted of:

(1) Converting an automatically controlled airplane into a bomb by the installation of distance equipment; and,

(2) Devising a radio control system for this flying bomb which could be controlled by an observer in an accompanying aircraft to direct the bomb to its target.[37]

He indicated that while radio control was of great importance, the immediate problem was one of launching the bomb. In a letter to Wilkinson, McCormick discussed the project and added a penned comment, "Next important step will be radio control of the torpedoplane from another plane at distance of 5 miles." [38] Four days later in another letter to Wilkinson he stated that

[32] Memorandum report, dated 13 Sept. 1916, from T. S. Wilkinson to the Chief of the Bureau of Ordnance.

[33] Minutes, Naval Consulting Board meeting of 14 Apr. 1917, National Archives, Washington, D.C.

[34] Letter, dated 9 May 1917, from Secretary of the Navy to W. S. Smith, 9 May 1917.

[35] W. S. Smith, "Chronology of Flying Bomb Work," 31 Jan. 1919, National Archives, Washington, D.C.

[36] Naval Consulting Board, North Sea Barrier File, National Archives, Washington, D.C.

[37] Letter, dated 10 July 1917, from B. B. McCormick to the Chief of the Bureau of Ordnance.

[38] Letter, dated 2 July 1917, from B. B. McCormick to T. S. Wilkinson.

Sperry advised him that radio control had been satisfactorily developed but that this work was being done by another company.[39]

Again, in a letter to the same officer he advised caution in applying radio control because enemy aliens were employed in the radio section of the Sperry Co., and also because of the need of first developing a stable missile. He continued, stating that when some satisfactory shots had been achieved and when the enemy aliens have been removed he would be ready to turn over whatever was provided by Hooper, Head of the Radio Division, Bureau of Steam Engineering.[40]

Meanwhile, on 11 August, Mr. M. M. Titterington, of the Sperry Co., had written Hooper advising him that the Western Electric Co., was developing a radio-command system for the flying bomb. He solicited the Bureau's interest and sponsorship of this project.[41]

In later correspondence with Wilkinson, McCormick reported that he had visited the Western Electric Co., plant and had inspected their radio-control system and, in his opinion, it was satisfactory and ready for delivery when sufficient progress had been achieved to warrant its use.[42] In a letter of 24 September he advised that the Sperry Co., was attempting to develop a radio-control system, but that he did not encourage this because of the work already accomplished by the Western Electric Co.[43] Despite McCormick's lack of support, the Sperry Co. continued its work on the radio-control problem and on 18 December 1917 applied for its first patent in this field, issued as U.S. Patent No. 1,792,938.

The design of these early systems of radio control envisioned control of the flying bomb only after it was airborne. This necessitated getting the plane airborne by catapulting. This imposed additional requirements of providing a plane sufficiently rugged to stand the rapid acceleration required and possessing a high degree of inherent stability. Additionally, the automatic control system had to be designed to function without being adversely affected by the rapid acceleration of launching.

Several methods of catapulting were attempted during the next 6 months and,[44] finally, on 6 March 1918 the first successful flight of an automatic missile was made.[45] The launching was accomplished from an impulse-type catapult powered by a 5,000-pound concrete block dropping a distance of 30 feet and transferring its motion to the catapult car through a system of cables and pulleys. The automatic distance gear was set to cut the throttle of the plane, which was an experimental design of the Curtis Co., after it had traveled 1,000 yards. The plane catapulted cleanly, climbed steadily, and flew in a straight line. The distance device functioned at about 1,000 yards, after which the plane went into a spiral and struck the water without being greatly damaged.[46]

Another launching was attempted on 7 April. The plane was successfully catapulted, but it failed to rise, settled on the ground, and was wrecked. Despite the pre-

[39] Letter, dated 6 July 1917, from B. B. McCormick to T. S. Wilkinson.

[40] Letter, dated 21 Aug. 1917, from B. B. McCormick to T. S. Wilkinson.

[41] Letter, dated 11 Aug. 1917, from M. M. Titterington to S. C. Hooper.

[42] Letter, dated 19 Sept. 1917, from B. B. McCormick to T. S. Wilkinson.

[43] Letter, dated 24 Sept. 1917, from B. B. McCormick to T. S. Wilkinson.

[44] Letters dated 8 Dec. 1917 and 18 Jan: 1918, from B. B. McCormick to the Chief of Bureau of Ordnance.

[45] One 14 Sept. 1914 the Italian Army launched a plane equipped with a gyro control system which rose to a heigh of 20 feet and then crashed (Edgar Buckingham, 11 Oct. 1918).

On 21 March 1917 the British Army conducted the first partially successful flight using radio control. The plane was launched by a pneumatic catapult from a lorry. The first radio signal was "up," the second "left," and the third "flatten out." These were answered, but, on a second "left" signal the plane made a partial loop, the engine failed and the plane crashed (statements of Maj. A. M. Low and Chief Wireless Officer G. W. M. Whitton, of the Royal Flying Corps).

[46] Letter, dated 8 Mar. 1918, from B. B. McCormick to the Chief of the Bureau of Ordnance.

vious successful launching it was decided that the flight characteristics of the plane required improvement and that a better method of catapulting than that provided by the weight-powered impulse type was desirable.[47] An attempt at launching from an automobile equipped with wheels fitted to a railroad track was unsuccessfully attempted on 17 May.

A month prior to this launching, McCormick had recommended the design of a flywheel-powered type of catapult. The Sperry Co. was directed to proceed with this. They procured the services of Mr. Carl L. Norden, a consulting engineer, who later achieved fame by his design of a stabilized bombsight, to perform the mathematical calculations and design. The genius of Norden was to affect the course of the entire project profoundly. His report on the preliminary work, dated 15 May 1918, recommended a wheel which, revolving at 2,175 r.p.m., would accelerate a mass of 1,950 pounds to a final speed of 100 m.p.h. over a track 150 feet in length. On 24 May he was directed to proceed with the construction of two flywheel-powered catapults.[48]

A successful launching was made, utilizing this new type of catapult, on 23 September 1918, but after becoming airborne the plane performed erratically and crashed. This further strengthened the opinion that a more rugged plane with better inherent stability was required.[49] Another test using the last of three especially designed Curtis planes was conducted on 26 September with like result.

On 3 September McCormick recommended that one of the N–9 training planes, provided by the Navy at the commencement of the project, be fitted for catapulting and automatic control.[50] This recommendation was approved and, on 17 October 1918, the plane was catapulted. After leaving the catapult it climbed steadily and flew in a straight line which deviated about 2° to the left of its preset course. The distance-controlling device, set for 14,500 yards, failed to function and the plane continued on its course and was last seen flying eastward at 4,000 feet.[51]

McCormick, highly impressed with Norden's ability, had asked him to recommend the course for future development of the flying bomb. Norden completed this study on 30 October 1918, recommending better designed planes capable of carrying a check pilot during tests and redesign of the automatic control system so that it could be cut in or out at the will of the check pilot.[52]

Carrying out Norden's recommendations, new specifications covering the design of the plane were drawn up in cooperation with the Witteman-Lewis Co. which was given a cost-plus-fixed-fee contract to provide five flying-bomb planes capable of carrying a check pilot. On 26 February 1919 the first of these planes was ready for flight tests. In the interim, Norden designed automatic control equipment which could be thrown in or out by the check pilot.[53] Three sets of this equipment were constructed at the plant of the Ford Instrument Co., and the Witteman-Lewis Co. was requested to purchase them under their cost plus contract. Two complete sets of Sperry automatic control equipment remained from those previously purchased.[54]

Except for the provision of services, McCormick's actions had practically eliminated the Sperry Co. from the project. In late 1918 he recommended the entire project be relocated at a naval station. This was agreeable to the Sperry Co.[55] By 27

[47] Memorandum, dated 8 Apr. 1918, from George Blair to T. S. Wilkinson.

[48] Letter, dated 24 May 1918, from B. B. McCormick to Carl L. Norden.

[49] Letter, dated 30 Sept. 1918, from A. J. Stone to the Chief of the Bureau of Ordnance.

[50] Letter, dated 3 Oct. 1918, from B. B. McCormick to the Chief of the Bureau of Ordnance.

[51] Bureau of Aeronautics technical report prepared by D. S. Fahrney, N59–318, p. 111.

[52] Ibid., p. 113.

[53] Ibid., p. 115.

[54] Letters, dated 25 Jan. and 14 Feb. 1919, from B. B. McCormick to the Chief of the Bureau of Ordnance.

[55] Letter, dated 2 Jan. 1919, from Elmer Sperry to Chief of the Bureau of Ordnance.

May 1919 the move had been completed and work commenced at the Lower Station, Naval Proving Ground, Dahlgren, Va.,[56] under the direction of Capt. T. T. Craven, USN, Inspector of Ordnance in Charge.

Upon completion of the move to Dahlgren it was discovered that the Witteman-Lewis Co. planes were tail heavy and that the ailerons and tail surfaces were too small, thus making the plane dangerous to fly.[57] No further flights, except by the Witteman-Lewis Co. test pilots, were made pending completion of changes to the planes.[58] Prior to this discovery the catapult had been installed and tested, and three of the new planes had been fitted with Norden equipments and satisfactorily tested under similated flight conditions.

On 24 October 1919 Norden recommended that the projects be expanded to include the fitting of obsolete planes for use as antiaircraft targets and that automatic pilots be used in spotting planes. He further stated that radio-controlled planes would require automatic controls.[59]

The necessary modifications to the planes were completed during the winter of 1919–20 and further experimentation was authorized to commence on 30 April 1920, except that no piloted flights were to be launched from the catapult without the authorization of the Bureau of Ordnance.[60] The first catapult launching was made on 18 August. The plane became airborne and flew straight for a distance of 150 yards, stalled, nosed over, and dived into the Potomac River. Norden deduced that this was caused by the closing of the throttle during the acceleration of the plane on the catapult and by insufficient electrical power being generated by the windmill generator. He recommended that a pilot be allowed to flight test each flying bomb to make proper adjustments to the automatic control equipment before it was catapulted without a pilot. This recommendation was approved by the Chief of the Bureau of Ordnance.[61]

The next trial was conducted on 18 November after the plane had been subjected to a flight test during which the automatic controls worked satisfactorily. The launching was perfect, the plane became airborne, climbed slowly, and completed one circle and then reached an altitude of 1,500 feet after traveling a distance of 5 miles. It continued circling and climbing until it reached an altitude of 7,000 feet, at which time the automatic closing of the throttle functioned, the plane went into a spin, and then into a nosedive during which the wings crumpled when about 300 feet above the water.[62]

A plane was launched on 25 April 1921, climbed for a short distance and then settled slowly, came in contact with the water and upset. During the flight of almost 2 minutes there were no signs of poor stability. Norden was of the opinion that he erred in making the initial horizontal stabilizer setting.[63]

The Bureau of Ordnance's interest in the flying bomb suddenly commenced to wane. In a letter to the Chief of Naval Operations, the Chief of that Bureau indicated his intention to discontinue further tests unless otherwise directed.[64]

[56] Memorandum, dated 27 May 1919, from T. S. Wilkinson to the Chief of the Bureau of Ordnance.

[57] Letter, dated 23 Oct. 1919, from W. B. Haviland to the Chief of Naval Operations.

[58] Letter, dated 21 Oct. 1919, from the Chief of the Bureau of Ordnance to Inspector of Ordnance in Charge, U.S. Naval Proving Ground, Dahlgren, Va.

[59] Letter, dated 24 Oct. 1919, from Carl L. Norden to O. M. Hustvedt.

[60] Letter, dated 30 Apr. 1920, from Chief of the Bureau of Ordnance to Inspector of Ordnance in Charge, Naval Proving Ground, Dahlgren, Va.

[61] Letter, dated 27 Aug. 1920, from Chief of the Bureau of Ordnance to Inspector of Ordnance in Charge, Naval Proving Ground, Dahlgren, Va.

[62] Report, dated 21 Nov. 1920, from Carl L. Norden to the Chief of the Bureau of Ordnance.

[63] Bureau of Aeronautics Technical Report, op. cit., p. 122.

[64] Letter, dated 27 Apr. 1921, from Chief of the Bureau of Ordnance to the Chief of Naval Operations.

NAVY RESEARCH, DEVELOPMENT, AND EXPERIMENTATION WITH RADIO CONTROLLED AIRCRAFT

On 30 December 1920 the Chief of Naval Operations appointed a board consisting of Capts. L. A. Bostwick, W. G. DuBose, A. S. Hepburn, and C. C. Block, USN, to investigate and report upon the feasibility of the remote control of aircraft by radio.[65] This Board recommended that the Navy undertake the project and that it should be placed under the cognizance of the Bureau of Ordnance.[66] On 20 January 1921 the Secretary of the Navy approved these recommendations.

Activation of this project was slow. In late October 1921 Lt. Comdr. O. M. Hustvedt, USN, of the Bureau of Ordnance, accompanied by Radio Aid A. Crossley, of the Bureau of Engineering, made several visits to the Naval Proving Ground, Dahlgren, Va., discussed the inactive flying bomb project, and formulated procedures for carrying out the radio-control project.[67] These procedures were, for the most part, approved. The design, development, and tests of the radio equipment were made the resonsibility of the Bureau of Engineering and were initially carried out at the Naval Aircraft Radio Laboratory at Anacostia, under the direction of Dr. A. Hoyt Taylor. The installation of equipments in planes and flight tests were to be accomplished at Dahlgren under the supervision of the Bureau of Ordnance.

On 17 January 1922 the Chief of the Bureau of Engineering advised the Chief of the Bureau of Ordnance that his Bureau was ready to proceed on the project. Funds were made available by Ordnance and on 28 January the Aircraft Laboratory was directed to begin the work.[68]

Meanwhile, Hooper, at this time on his second tour of duty as Head of the Radio Division, Bureau of Engineering, had procured the services of Mr. C. B. Mirick and had assigned him to the Laboratory as an assistant to Taylor to carry on this work.[69] Mirick, an excellent radio engineer, had served with Taylor as an ensign during the war and had considerable experience with aircraft radio problems.

Before beginning design of a system, Mirick made a tour of various establishments to determine the best type of components available for the projected system. The most productive visit was the one to the Hammond Co., where he found that the components of the radio-control equipment for the standard Navy torpedo were being redesigned so that it could be assembled in small units capable of being installed and serviced through handholes in the radio-control section of the torpedo.[70]

By midsummer, Mirick selected the following components for the aircraft radio control system:

(1) A continuous-wave transmitter modulated to produce an audible frequency;

(2) A device for keying Baudot code;

(3) An amplified receiver capable of tuning a nondirectional aircraft antenna to the frequency of the transmission;

(4) A sensitive, mechanically tuned, vibrating relay capable of being adjusted to the pitch of the modulated signal;

(5) A secondary relay; and,

(6) The Morkum teletype selector operating on the Baudot impulses.

With the exception of satisfactory relays, these components were readily available.[71] Several types of relays were developed and tested within a few months. One developed by the Naval Aircraft Radio Laboratory proved superior.[72] The components were assembled and tested at the Laboratory and

[65] Memorandum, dated 30 Dev. 1920, from Chief of Naval Operations to L. A. Bostwick.

[66] Report, dated 17 Jan. 1921, from L. A. Bostwick and other Board members to the Secretary of the Navy.

[67] Memorandum, dated 21 Oct. 1921, from O. M. Hustvedt to the Chief of the Bureau of Ordnance.

[68] Letter, dated 28 Jan. 1922, from Bureau of Engineering to Naval Air Station, Anacostia, D.C.

[69] Letter, dated 28 Nov. 1921, from A. Crossley to the Chief of the Bureau of Engineering.

[70] Report, dated 25 Apr. 1922, from C. B. Mirick to the Chief of the Bureau of Engineering.

[71] Report dated 15 June 1922, from C. B. Mirick to the Chief of the Bureau of Engineering.

[72] Report dated 3 Nov. 1922, from Naval Air Station, Anacostia, D.C., to Bureau of Engineering.

later in a piloted F-S-L flying boat about 15 April 1923.[73]

On 11 May 1922, the Bureau of Ordnance directed the Proving Ground, Dahlgren, to proceed without delay to get one of the N-9 aircraft that had been used in the flying-bomb experiments and was fitted with the Norden automatic control system ready for the installation of the radio-control system by 1 July. The radio-control equipment was not ready by that date and was not fitted into the N-9 plane until July of the following year. Norden used this year of grace to further perfect the automatic pilot and to advise the Naval Research Laboratory, which had absorbed the Naval Aircraft Radio Laboratory in April 1923, relative to the linkage requirements between the two control systems.[74]

Mirick completed the radio-control installation in the N-9 plane on 21 July 1923.[75] The automatic pilot with its ancillary equipment weighed 130 pounds and the radio-control equipment weighed 148 pounds.[76] The latter consisted of a triangular antenna running from the wing skid fins to the rudder post; a receiver with a six-stage amplifier, designed by Dr. J. M. Miller, of the Naval Research Laboratory; the relays, and the Morkum selector to actuate the proper relay according to the signal received.[77] The radio equipment at the control station consisted of a 1-kw. Marconi spark transmitter modified into an alternating current tube transmitter operating on 1200 kc. and capable of providing an antenna current of about 8 amperes.[78] This transmitter was keyed by a pushbutton device which transmitted Baudot code.

Prior to 3 August, the plane had been controlled in the air with a safety pilot in simple maneuvers up to distances of 5 miles. The relays were tested satisfactorily to distances of 20 miles. The rudder control was found ineffective when the plane was taxied on the water because the radio control was adjusted for flight speeds.[79]

Between 18 May and 14 November, 33 test flights were made, all with Lt. J. J. Ballantine, USN, as safety pilot. In the final test of 1923, held on the latter date, a successful demonstration was made before officers of the Bureau of Ordnance. During this 45-minute flight, radio control was used about 25 minutes. Two down-elevator, three up-elevator, six left and five right turns were made by radio control in addition to a number radio signal operating a dummy throttle.[80] Following the conclusion of this test it was decided to discontinue operations until spring without attempting a pilotless flight.[81]

During the winter the radio-control components were improved by the Laboratory and two Vought seaplanes, provided by the Bureau of Aeronautics,[82] were equipped with automatic pilots, and an HS flying boat was fitted as an airborne control station. Snap switches were installed in the cockpit to permit the pilot to cut out the entire radio-control system instantly. Flights to test out the improved equipment and the procedure for the use of the airborne control station were resumed on 24 July 1924.[83]

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[73] Report dated 15 Apr. 1923, from C. B. Mirick to the Chief of the Bureau of Engineering.

[74] Bureau of Aeronautics technical report, op. cit., p. 158.

[75] Letter, dated 10 Sept. 1923, from the Director, Naval Research Laboratory to the Chief of the Bureau of Engineering.

[76] Report, dated 18 Dec. 1923, from J. J. Ballantine to the Chief of the Bureau of Ordnance.

[77] Report, dated 15 Apr. 1923, from C. B. Mirick to Director, Naval Research Laboratory.

[78] Report, dated 7 Feb. 1923, from C. B. Mirick to Director, Naval Research Laboratory.

[79] Letter, dated 10 Sept. 1923, from Director, Naval Research Laboratory, to the Chief of the Bureau of Engineering.

[80] Report, dated 18 Dec. 1923, from J. J. Ballantine to the Chief of the Bureau of Ordnance.

[81] Letter, dated 8 Dec. 1923, from Chief of the Bureau of Ordnance to the Director, Naval Research Laboratory.

[82] Letter, dated 27 Dec. 1923, from the Chief of the Bureau of Ordnance to the Chief of the Bureau of Aeronautics.

[83] Report, dated 17 Oct. 1924, from J. J. Ballantine to Inspector of Ordnance in Charge, Naval Proving Ground, Dahlgren.

On 15 September two test flights were made in the N–9 plane during which the automatic stabilization and the radio-control systems functioned perfectly. It was then beached and readied for its first pilotless flight. A bag of sand was securely lashed to the pilot's seat to compensate for his weight. The HS flying boat took station in order to assume radio control if so signaled. The radio and gyro switches were turned on, the motor started, and the wings were held level for 5 minutes to insure that the gyros came up to speed and settled down on course. The rudder gyro was then unlocked, the "on throttle" signal was given by the radio-control station, and the N–9 released. The plane became airborne and was directed through a long series of maneuvers. From the takeoff to the landing, which covered a period of 40 minutes, over 50 signals were made and, except for the right-turn signal, answered promptly. This failure was discovered to be caused by excessive sparking at the transmitter keyboard control and the difficulty was eliminated by reducing power.[84] For the first time in history a pilotless aircraft had been put into the air, controlled through many maneuvers, and landed.[85] Credit for this achievement belongs to many, but above all to Taylor, Mirick, and Chief Radioman Elmer Luke, USN, of the Research Laboratory; to Norden, of the Bureau of Ordnance; and to Ballantine and Mr. C. C. Middlebrook, of the Naval Proving Ground.

After the flight of 15 September, the radio-control equipment was transferred to the newer Vought plane.[86] This installation was completed and the plane was flight tested without automatic pilot control prior to 24 December 1924, on which date flight operations were concluded for the remainder of the winter.

Flight operations were resumed on 19 June 1925 and, by 14 September, 28 test flights had been made, none of which were completely successful. On the latter date Ballantine was relieved by Lt. V. H. Schaeffer, USN. On 28 October a successful test was made with a safety pilot in the cockpit and from that date until the test without a pilot several successful flight tests were made.[87]

On 11 December a pilotless flight was attempted under ideal weather conditions. The "on throttle" signal was transmitted, the engines tuned up full speed, the plane started along the takeoff course holding an apparently straight course before leaving the water. Just after being airborne the plane porpoised and struck the water four times, bouncing higher each time. After striking the last time the pontoon struts gave way, the nose of the pontoon was cut off by the propeller, the plane nosed up and sank.[88]

Schaeffer concluded that the failure was caused by the jerky actions caused by the Baudot transmissions and recommended no further pilotless flights until the equipment was modified to give a more graduated and smoother control.[89] This condition had been noted by Mirick, and the Naval Research Laboratory had developed a "tuned relay system" which utilized normal pilot controls instead of pushbuttons and gave a much greater degree of control and an almost instantaneous response by the aircraft. Additionally, several controls could be actuated simultaneously.[90]

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[84] Ibid.

[85] As mentioned in footnote 35, the Royal Air Corps had controlled a plane for a few seconds on 21 Mar. 1917 (Prof. A. M. Low, Flight, 3 Oct. 1952). Experiments in radio control of aircraft were conducted in France during 1918 and 1919. Although the plane could be put into the air, maneuvered and landed, no flights were attempted without a safety pilot (Radio News, December 1923).

[86] Letter, dated 24 Sept. 1924, from C. B. Mirick to Superintendent, Radio Division, Naval Research Laboratory.

[87] Memorandum, dated 15 Dec. 1925, from V. H. Schaeffer to the Inspector of Ordnance in Charge, Naval Proving Ground, Dahlgren.

[88] Letter, dated 30 Dec. 1925, from V. H. Schaeffer to the Inspector of Ordnance in Charge, Naval Proving Ground, Dahlgren.

[89] Ibid.

[90] Letter, dated 9 Dec. 1924, from Director, Naval Research Laboratory, to the Chief of the Bureau of Engineering.

Late in 1924 the Laboratory reported it was feasible to control a plane by radio beyond the range of vision.[91] However, the project was beginning to follow the pattern of that of the flying bomb. Interest waned, and no action was taken on the Laboratory's report. Proposals were made to improve the control equipment, but no action was taken on these. During the next 3 years improved radio-control apparatus was developed, but no further flights were attempted. The project was not canceled, but remained almost dormant until 1936.[92] The developments of that year will be covered in a later chapter.[93]

[91] Letter, dated 22 Nov. 1924, from Chief of the Bureau of Engineering to the Secretary of the Navy.

[92] During the next decade several attempts were made to reactivate the project. None of these were successful due to lack of funds and differences of opinions of the several material bureaus relative to its feasibility and cognizance. When it was finally reactivated in 1936 it was for the purpose of providing the necessary target training for antiaircraft batteries. So great was the success of the project to provide such targets that it became the progenitor of the flying-missile program (second endorsement by the Chief of Naval Operations on a Bureau of Engineering letter of 29 Mar. 1933; Letter, Bureau of Engineering to the Bureau of Ordnance dated 17 Mar. 1926; second endorsement of the Bureau of Aeronautics on a Bureau of Ordnance letter addressed to the Chief of Navl Operations, dated 27 Oct. 1932).

[93] The author desires to express his appreciation to Rear Adm. D. S. Fahrney, USN, (retired) for the assistance afforded him by his research into the history of radio-controlled aircraft.

CHAPTER XXX

The Navy and the Radio Corporation of America

MARCONI INTERESTS ENDEAVOR TO STRENGTHEN BRITISH DOMINATION

Immediately following the end of World War I, the British Marconi interests reopened negotiations for the exclusive use of the Alexanderson alternator. They offered to purchase 24 complete transmitters for $3,048,000, but the General Electric Co. preferred to provide them on a royalty basis. This was not satisfactory to the Marconi Co. which countered with an offer of an additional $1 million to defray development costs.[1]

THE NAVY OPPOSES THE ALTERNATOR SALE

News of these negotiations was reported to Hooper who, in turn, warned Secretary Daniels of their implications. Daniels, still waging his unsuccessful campaign for Government ownership of radio, was considerably alarmed by this information. At Hoopers' suggestion he directed that Rear Admiral Bullard be ordered to reassume duties as the Director, Naval Communications in order that a person of sufficient stature should direct the fight against the British monopoly. Bullard, who was then on duty in the Near East, was directed to return by way of Paris to confer with Daniels, who accompanied the President to Paris on his second trip to the Peace Conference, and with Todd, recently relieved as Director and at the time on leave in that city.[2]

In his conference with the Secretary, Bullard advised him that he did not concur in the establishment of a Government radio monopoly and requested another assignment if it was required that he support such a policy. He received the Secretary's assurance that it was not necessary for him to do so. There is no available record of the instructions given Bullard by Daniels at this meeting. His subsequent actions as Director, Naval Communications, indicate that he had received some instructions, possibly secret ones, either directly or indirectly from the President.

Meanwhile Hooper, at the Secretary's direction, asked Mr. E. P. Edwards of the General Electric Co. to request that company's officials to withhold action on the Marconi sale until Bullard arrived and resumed his old duties. They acquiesced to this request.[3] On 29 March 1919, Mr. Owen D Young wrote Franklin D. Roosevelt, acting Secretary of the Navy, disclosing the full details of the proposed sale. On 4 April Roosevelt replied to Young, inviting the officials of the General Electric Co. to Washington for a conference on 11 April. This letter stated:

> Due to the various ramifications of this subject it is requested that before reaching any final agreement with the Marconi Companies, you confer with representatives of the department.

[1] W. Rupert Maclaurin, "Invention and Innovation in the Radio Industry" (the Macmillan Co., New York, 1949), p. 100.

[2] S. C. Hooper, "History of Radio, Radar and Sound in the U.S. Navy" (Office of Naval History, Washington, D.C.), 10R.

[3] Ibid.

It is significant that this was written 4 days after Bullard resumed his duties as Director and the tenor of the above quoted sentence indicates that the Navy Department was in possession of a directive, probably oral, to take action to safeguard American radio interests.

PRESIDENT WILSON'S INTEREST IN AMERICAN DOMINATION OF RADIO

The part played by the President in the endeavor to gain American radio supremacy did not come under scrutiny until 1929. By that time both he and Bullard were dead. However, it must be assumed that the President was aware of the official activities of the members of his Cabinet and was cognizant of the Navy Department's endeavor to establish a Government radio monopoly. Following the defeat of his party in the congressional elections of 1918 he must also have realized that Daniels would fail to reach his objective.

On 12 February 1919, while attending meetings of the Peace Conference in Paris, he was presented a masterly brief on world communications by Mr. Walter S. Rogers, communication expert to the American Commission to Negotiate Peace. This brief pointed out the possibility of utilizing high-power radio for disseminating intelligence to the ends of the earth, recounted the success of the British in the domination of cable communications, and pleaded for the fair use of international communications. In reading this brief, the President must have recalled the psychological effect produced by the telegraphic broadcasts of his "Fourteen Points" and the parts played by the American and German radio stations in the arrangements for the armistice.[4]

On 15 February he departed France for the United States and arrived back on his second trip on 14 March. During the 18 days he was aboard the U.S.S. *George Washington,* his sole touch with world affairs was through the naval radio system. On the westbound journey he had conversed with Secretary Daniels by radiotelephone when 900 miles distant from New York. It must also be assumed that since he was accompanied by Secretary Daniels on the eastbound voyage, the two discussed the failure to establish the Government monopoly and the possibility of establishing an American-controled operating company.

On the day following his return to Paris, he received a cable from Postmaster General Burleson inviting his attention to the British domination of world communications.[5]

With almost constant reminders of the importance of international communications, the President, shortly after his return to Paris, received still another which apparently forced him to make a decision. While breakfasting with Prime Minister Lloyd George and some of their assistants, an officer delivered the Prime Minister a telegram. After reading its contents he turned to the President and commented upon the importance of the world radio system. Following breakfast, the President went motoring with his physician, Rear Adm. Cary T. Grayson, (MC) USN. During this drive he directed Grayson to remind him to tell the Navy Department or Bullard that he had an important message for delivery to Mr. Owen D Young concerning "the protection of American rights and possibilities in radio communications." [6]

THE THWARTING OF THE MARCONI PLANS

On 31 March 1919 Bullard reported for duty as Director, Naval Communications.

[4] Supra, chap. XXV.

[5] Ray Stannard Baker, "Woodrow Wilson and World Settlement," vol., III, p. 425.

[6] Testimony of Rear Adm. Cary T. Grayson (MC) USN, before a Senate committee in 1929. The date of this directive was something between 16–21 March 1919 at which time the President and Bullard were concurrently in Paris. Bullard sojourned at the same hotel as the President.

Three days later Hooper apprised him of the alternator situation. Bullard later stated that this was the first time that the impending sale of the alternator was brought to his *official* attention.[7] There is no record that he informed Hooper of his possession of any directive. Obviously he must have discussed the situation with the Acting Secretary and received additional instructions, for his first action in this matter was to arrange for a conference with Young in New York on 7 April. This occurred at about the same time Roosevelt was signing the letter to Young. Bullard would not have circumvented the proposed conference in Washington without Roosevelt's approval. In fact, it is probable that it was the latter's idea for Bullard to proceed without delay.

The initial conference, held in Young's office on 7 April, was attended by Young, Bullard, and Hooper. The second one, held the following day, was attended by the president of the General Electric Co., Mr. Edwin W. Rice, Jr., and directors Young, A. G. Davis, C. W. Stone, and E. P. Edward as well as Bullard and Hooper. Later, Young conferred with the chairman of the board of the General Electric Co., Mr. C. A. Coffin, after which that official joined the meeting.

At some time during these 2 days (the exact hour obscured by several varying versions)[8] Bullard informed Young of the President's interest in the matter and that he had been directed to enlist his aid in the establishment of an American-controlled commercial radio company.

During the 8 April conference Bullard pleaded for an American radio monopoly and argued that the sale of the alternator to the Marconi interests would ensure the British a monopoly in world communications. The directors of the company, though desirous of selling the alternator to an American-controlled company, pointed out that there was no company capable of making such a purchase and their duty to

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[7] U.S. Naval Institute Proceedings, vol. 49, October 1923, p. 1630. The underscoring is the author's.

[8] Dr. Gleason L. Archer states that Young gave him this account on 5 February 1937:

"Admiral Bullard and Commander S. C. Hooper came to my office, and Admiral Bullard said that he had just come from Paris, at the direction of the President, to see me and talk about radio.

"He said that the President had reached the conclusion, as a result of his experience in Paris, that there were three dominating factors in international relations—international transportation, international communication, and petroleum—and that the influence which a country exercised in international affairs would be largely dependent upon their position of dominance in these three activities; that Britain obviously had the lead and experience in international transportation—it would be difficult if not impossible to equal her position in that field; in international communications she had acquired the practical domination of the cable system of the world; but there was an apparent opportunity for the United States to challenge her in international communications through the use of radio; of course as to petroleum we already held a position of dominance. The result of American dominance in radio would have been fairly equal stand-off between the U.S. and Great Britain—the United States having the edge in petroleum, Britain in Shipping, with communications divided—cables to Britain and wireless to the United States.

"Admiral Bullard said the President requested me to undertake the job of mobilizing the resources of the nation in radio. It was obvious that we had to mobilize everything we had, otherwise any of our international neighbors could weaken us tremendously by picking out one little thing. The whole picture puzzle had to be put together as a whole in order to get an effective national instrument.

"At this time Mr. A. G. Davis was working with Mr. Steadman of the Marconi Company, who had come over here again, and the General Electric Company was about to conclude an agreement to sell about five million dollars worth of apparatus, with everything settled except the amount of royalty payments to be paid to use on the basis of so much per word transmitted via the alternators. By this time we were not content merely to sell the apparatus—we wanted a royalty on the traffic in addition. At this stage we were asked not to sell the Alexanderson alternator to either the British or American Marconi Companies—and there were no other prospective customers for that kind of apparatus.

"I asked Admiral Bullard what impressed President Wilson about radio. He said the President had been deeply impressed by the ability to receive all over Europe messages sent from this side—particularly the fact of the broadcast (i.e., by radio telegraph) across all international boundaries from this country by the Alexanderson alternator of his their stockholders necessitated recovering the monies spent in the development of the device.[9]

This may have been the moment when Young conferred with the chairman of the board and imparted the information provided him by Bullard relative to the concern of President Wilson. After additional eloquent appeals to their patriotism, the directors voted to cease their negotiations with the Marconi interests. No plans concerning the sale of the alternator were made at this meeting.

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own "Fourteen Points," Bullard said he had been into some of the Balkan states and there found school children learning the Fourteen Points as they would learn their catechism—made possible by the Alexanderson alternator at New Brunswick, New Jersey, which, defying all censorship, was stimulating in everybody everywhere a deep anxiety that the war should end" (Gleason L. Archer, History of Radio to 1926.) (American Book-Statford Press, Inc., New York 1938), pp. 164–165).

". . . Admiral Bullard explained President Wilson's part in the affair not in open conference but privately during a lull in the conference of April 8, 1919. At that moment there was uncertainty as to what action the directors might take. The naval officer called Mr. Young aside and imparted the information as a state secret, saying that President Wilson was deeply concerned over the matter of checkmating British domination of wireless and had given him as Director Naval Communications special instructions with reference to American control of the Alexanderson alternator. For diplomatic reasons the head of the nation could not openly show his hand in the matter." (Archer, op. cit., footnote p. 163).

Dr. Rupert Maclaurin quotes the following from an interview with Young in August 1944:

"When Admiral Bullard arrived in my office, he said the President, whom he had just seen in Paris, was concerned about the post-war international position of the United States and had concluded that three of the key areas on which international influence would be based were shipping, petroleum and radio. In shipping England was supreme and the United States could not rival her position. On the other hand, in petroleum, England could not challenge America's position. But in radio, the British were now dominant and the United States, with her technical proficiency, had an opportunity to achieve at least a position of equality" (Maclaurin, op. cit., p. 101).

[9] Testimony of Owen D Young before the Senate Committee on Interstate Commerce, 11 January 1921.

CONCEPTION OF AN AMERICAN-CONTROLLED RADIO COMPANY

The decision to terminate negotiations with the Marconi companies left the General Electric Co. in an awkward position. They had spent over $1 million developing an apparatus for which there now was no ready market. Within a few days Young appeared in Washington requesting an appointment with Bullard and Hooper. It was arranged that they meet in the admiral's office. As was to be expected the subject of the conference was, "What do we do with the alternator?" It was suggested that the General Electric Co. establish an international communication system which would use the alternator.[10] Young agreed that this was a possible solution but opined that it would not be successful without a Government charter authorizing a monopoly. The Navy representatives agreed to aid in obtaining this. Lt. Comdr. E. N. Loftin, USN, was assigned to assist Mr. A. G. Davis, patent attorney for the General Electric Co., in drafting the proposed charter.

The draft was completed by 30 May 1919. It contained, among other things, a promise on the part of the Navy Department, upon the request of the General Electric Co., to recommend and to urge Congress to grant the proposed Radio Corp. an American monopoly covering low-frequency radio communications. Other provisions of this draft contained cross-license agreements between the Government and the General Electric Co., the promise of the Navy Department to assist in the procurement of other licenses and patents, and an agreement that a high ranking naval officer would sit in on board meetings to protect Government interests.

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[10] The February 1921 issue of The Wireless Age, p. 13 attributes the suggestion to Bullard. George H. Clark in an unpublished manuscript. "The Formation. Of the Radio Corporation of America," p. 45 claims it was made by Hooper. ("Radioana," Massachusetts Institute of Technology, Cambridge, Mass.) Owen D Young, in several letters to Hooper, credits the latter with the suggestion.

The draft contained no statement relative to the manufacture or sale of equipment by the proposed corporation which by inference, was to be solely a radio operating company.

The draft was forwarded to Acting Secretary of the Navy Roosevelt who had been kept fully informed of the proceedings. He had encouraged and approved the several actions. However, Admiral Griffin, Chief of the Bureau of Steam Engineering, who was with the Secretary in Paris, was not so well informed. Hooper cabled him information concerning the proposed charter and requested instructions. Griffin referred the message to the Secretary who directed that action be held in abeyance until his return. This information was provided General Electric officials in late May.[11]

Upon being informed that the General Electric Co. would not provide the Marconi companies with alternators, Nally, vice president and general manager of the American Marconi Co., made an entry in his diary, under the date of 25 April 1919, in which he commented upon the existence of this unfortunate state of affairs and the Navy's determination to eliminate foreign influence from American radio operating companies. He indicated an awareness of the fact that some American company was about to enter the field in competition with Marconi and noted that the only apparent solution to the problem was for this company, which he suspected to be General Electric, to buy out the British interests.[12]

In another diary entry of the same date, Nally made reference to a previous conversation with Hooper which occurred about the beginning of World War I at the time when the American Marconi Co. was obtaining few Government orders. This conversation, as recorded by Hooper, was direct and to the point—his question equally so: "Other companies get Government orders, why can't we?" Hooper's answer was equally direct and frank, "Because there are a lot of things about your company we do not like." He further advised Nally that American Marconi should divest itself of British control and have its stock owned and controlled by Americans. Moreover, it would have to discard its policy of attempting to sell the Navy equipment which did not meet its requirement nor its specifications.[13] In justice to Nally he took these statements in the manner in which they were intended. The American company changed its sales methods and became a valuable asset to the Government during the war.

Late in April 1919 Nally, accompanied by Sarnoff, went to the Navy Department and requested a conference with Hooper. Again, as direct as before, he asked what was transpiring. Again, equally frank, Hooper told him of the effort being made to establish the new company, adding that the American members of the Marconi directorate were blameless but that it was necessary to eliminate foreign control from the United States international communications. Additionally, he told him that he would suggest that Young, if he headed up the new company, take in the personnel of the American Marconi Co. intact as the operating force of the new company.[14]

Hooper made this suggestion to Young who, in turn, on 12 May suggested to Nally that the American Marconi Co. join the General Electric Co. in forming the new corporation. In his diary entry of that date, Nally wrote that Young stated that the General Electric Co. preferred to stay out of the radio operating business, and did not desire to compete with American Marconi, but had to find a market for the alternator and, at the same time, maintain harmonious relations with the Government.[15] Thus did that premier of entrepreneurs pave the way for American Marconi officials to enter

[11] "Radioana," op. cit. letter, dated 30 May 1919, from A. G. Davis to O. D Young, files, R.C.A.

[12] "Radioana," op. cit., George H. Clark, "The Formation of the Radio Corporation of America," undated and unpublished manuscript, pp. 53–54.

[13] Undated pencilled memorandum of S. C. Hooper, files, R.C.A. Ibid.

[14] Ibid., Clark, "History of the Formation of RCA," p. 56.

[15] Ibid., pp. 62–63.

the new company and convert Nally to the "cause."

Secretary Daniels returned from Europe about the end of May 1919. Shortly thereafter he reviewed the General Electric Co. Navy plan and discussed it at length with Bullard. A meeting was called by the Secretary which was attended by General Electric Co. and Navy officials. At this meeting he agreed that there was great value in the proposed agreement, and that he possessed full authority to sign it but, since it appeared to create a monopoly, he desired to discuss it with various colleagues in the Cabinet and Congress. While reiterating his objections to the American Marconi Co., because of its alleged domination by the English company, Daniels voiced his old views of the military necessity of Government ownership of radio, but he admitted doubt of his ability to convince Congress of the necessity for it.[16]

Young must have been completely surprised by this turn of events. He had every reason to consider that Bullard and Hooper had spoken authoritatively and that the Secretary would follow the advice of Roosevelt. Leaving Washington he asked Hooper's opinion as to whether a transoceanic company would pay dividends on the investment and was answered affirmatively.[17] What transpired at the next meeting of the board of directors of the General Electric Co. has never been completely divulged but they did decide to proceed with the organization of the Radio Corporation without further governmental blessing.

After making this decision, the General Electric officials notified Secretary Daniels that they were entering into negotiations with the American interests in the Marconi Wireless Telegraph Co. of America. Following this notification there is no record of further official correspondence requesting Navy support. In fact, within 30 months following this, Young stated that he had no knowledge of any executive department of the Government which could speak authoritatively in the radio field.[18]

The failure of Daniels to support his subordinates marked the beginning of a rapid diminution of the Navy's control of the Nation's radio policies. Young's relationship with Bullard and Hooper continued cordial and he did, from time to time, unofficially ask their opinions.

The negotiations with officials of American Marconi were successful, and an agreement was reached which was contingent upon the ability to purchase the British-owned stock of the American company. The proposed new corporation would purchase American Marconi tangible property with its preferred stock at par value and its patents, good will, and business assets with its common stock at no par value.

Nally and Davis sailed for England for the purpose of purchasing American Marconi stock for the new corporation. After 2 months of diplomatic and tactful discussions, aided by the belief of British Marconi officials that our Congress might enact legislation against the foreign control of wireless facilities located on the mainland, territories, or possessions of the United States, the reluctant directors of the parent company made the best of the situation. On 5 September they sold the General Electric Co. 364,826 shares of stock.

BIRTH OF THE RADIO CORPORATION OF AMERICA

With the controlling shares of American Marconi safely in hand, the Radio Corp. of America (RCA) was incorporated under the laws of the State of Delaware on 17 October 1919. Insofar as the personnel of the American Marconi Co. were concerned, the only difference noted after 20 November, when RCA took over the assets and business of that company, "'was a different

[16] Ibid., pp. 59–60.

[17] Ibid., pp. 61–62.

[18] "Radioana," op. cit., letter, dated 22 Dec. 1921, from the Radio Corp. of America to the Secretary of the Navy, signed by Owen D Young, files, R.C.A.

company name on the pay check."[19] The Marconi Co. retained its corporate identity for many years because of intangible assets which could not be evaluated until decisions were rendered in numerous pending patent infringement suits.

The Radio Corp. came into possession of the American Marconi patents, high-powered stations, its contract with the U.S. Shipping Board for the maintenance of the radio equipment on 400 of its ships, the Wireless Press, a corporation established for the purpose of publishing the American edition of the Marconi house organ, and three-eighths of the stock of the Pan-American Wireless Telegraph & Telephone Co.[20] This company had been chartered in Delaware under the joint ownership of the Federal Telegraph and American Marconi Cos. for the purpose of establishing radio circuits with Central and South American countries.

On the date of its incorporation, the Radio Corp. signed a cross-license agreement with the General Electric Co. by which both corporations were granted the free use of each other's radio patents, and the Radio Corp. became the exclusive U.S. sales agent for radio apparatus manufactured by the General Electric Co. In return for this concession the Radio Corp. agreed not to become a manufacturer.[21] Inasmuch as the Alexanderson alternator provided the best means of generating continuous waves and possessed the necessary power to ensure transoceanic radio communications, this gave the Radio Corp. a virtual U.S. monopoly in long-distance point-to-point communications.

For its expenditures, rights, and privileges the General Electric Co. received 135,174 shares of Radio Corp. preferred stock, par value $5 per share, and 2 million shares of common stock, no par value. The American Marconi interests received 2 million shares of common stock to be exchanged for that company's stock and a like number of shares of preferred stock for its assets, if on appraisal they were found to be worth $9,500,000, or a reduced number if the value proved less than that figure. Since the Radio Corp., under its cross-license agreement with General Electric, was prohibited from manufacturing, the Aldene, N.J., plant of the ex-Marconi Co. was purchased by the General Electric Co. for $500,000.[22]

Three of the articles of incorporation were of particular interest to the Government. One prohibited the election of a director or officer who was not a citizen of the United States. Another contained a prohibition that not more than 20 percent of the stock could be held and voted by foreigners and that those shares would carry "Foreign Share Certificate" printed on their faces. The third permitted participation in the administration of its affairs by the Government of the United States as the directors might vote advisable.[23]

Young was elected Chairman of the Board of Directors, Nally the president, and David Sarnoff the managing director.

One of the first actions of the Board of Directors was to invite President Wilson to nominate a naval officer of the rank of captain or above, regular Navy, to present the Government's views and interests concerning matters pertaining to radio communication at meetings of stockholders and directors.[24] In response to this request the Navy Department nominated Bullard. This was approved by President Wilson on 14 January 1920.[25] Bullard attended 29 of the 32 meetings held between 14 January 1920 and 28 July 1931. He later stated, "Who would not therefore feel proud to have

[19] "Radioana," op. cit., Clark, "The Formation of RCA," p. 71.

[20] Report of the Federal Trade Commission on the Radio Industry (Washington, Government Printing Office, 1924), p. 21.

[21] Ibid., pp. 21–22.

[22] Ibid., pp. 21, 126–130.

[23] Ibid., p. 19.

[24] "Radioana," op. cit., letter, dated 3 Jan. 1920, from E. J. Nally to President Woodrow Wilson, files, R.C.A.

[25] Ibid., Presidential approval of a letter of the Acting Secretary of the Navy, Rear Adm. Thomas Washington, dated 12 Jan. 1920, files R.C.A.

assisted in the successful development of such strong control of radio activities." [26]

In a letter addressed to Young, dated 14 February 1920, Hooper expressed his personal appreciation for the manner in which the General Electric Co. had patriotically responded to the Navy's appeal for the protection of American radio interests. The closing paragraph commended the work of Young and Davis and the attitudes of the directors.

Hooper later wrote an article entitled "Keeping the Stars and Stripes in the Ether" which was published in the June 1922 issue of Radio Broadcast. In this he gave credit for the formation of the Radio Corp. to Bullard, Young, and others and assumed no credit for himself. Young, commenting on the article to the editors of the magazine, stated that Hooper did not do himself justice since the initiative which brought into being our American radio policy and resulted in preventing other nations outdistancing us, started with him. He further commented that the original thought and the persistent pushing were Hooper's, and he should be fully credited with them.

Both Bullard and Hooper were offered, but refused to accept, posts in the new corporation. Neither of them accepted any gratuity for the services rendered, feeling that they were amply recompensed in the knowledge of duty well done.

GROWTH OF THE RADIO CORPORATION OF AMERICA

While the above was transpiring, congressional legislation had been enacted directing the Government to return to private ownership all telephone, telegraph, and cable facilities seized by it during the war. This was approved by President Wilson on 11 July 1919. The hour of return of radio station was fixed as 0000, 1 Mar. 1920.

Faced with the early return of the long-distance stations that had belonged to the Marconi Co., the Radio Corp., before the end of 1919, completed a traffic agreement with the British Marconi interests and began handling transatlantic communications on 1 March. Shortly thereafter the company established circuits with Japan and Norway in accordance with the former American Marconi traffic agreements with the governments of those countries.

Foreign domination of American radio communications had been effectively eliminated but, since no single company possessed sufficient patents to provide a complete system, there still remained the necessity for considerable cross-licensing and agreement between various corporations to insure the success of the Radio Corp.[27]

"Young was anxious to create an industry in which competition would be 'orderly and stabilized.' " [28] In order to do this he endeavored to bring all interested companies into the Radio Corp. In his first attempt he was aided and abetted by the Navy Department which had written similar letters to the American Telephone & Telegraph and General Electric Cos. requesting that they get together in order that the vacuum tube could be made available to the public and, also, that it might be further improved.[29]

Both companies, seeing the futility of noncooperation, readily agreed to cross-license their radio patents and to subdivide the field into telegraphic and telephonic uses. The agreement was signed 1 July 1920. The Telephone Co. purchased one-half million shares each of Radio Corp. preferred

[26] U.S. Naval Institute Proceedings, Annapolis, vol. 49, p. 1633.

[27] Owen D Young in testifying before the Committee on Interstate Commerce, U.S. Senate, 9 Dec. 1929, stated: "It was utterly impossible for anybody to do anything in radio, any one person or group or company at that time. The Westinghouse Company, the American Telephone and Telegraph Company, the United Fruit Company, and the General Electric Company all had patents but nobody had patents enough to make a system. And so there was a complete stalemate."

[28] Maclaurin, op. cit., p. 105.

[29] Infra, ch. XXIX.

and common stock for $2,500,000.[30] Unfortunately, the agreement between the two Radio Corp. corporate partners failed to envision the radio broadcasting boom which would engulf the country within a few months. The ambiguity of the agreement later caused considerable controversy which resulted in the Telephone Co. disposing of its Radio Corp. stock to the public.

The Radio Corp. sought a license to utilize the Government-owned patents which totalled over 140, including the Poulsen and the confiscated German patents, purchased from the Alien Property Custodian. The Navy Department's policy was to grant license to any American company which would cross license. The Radio Corp. refused to do this, and no further action was taken.

THE WESTINGHOUSE COMPANY ENTERS THE INTERNATIONAL RADIO COMMUNICATIONS FIELD

The Westinghouse Electric & Manufacturinng Co., which had enlarged its production facilities to provide radio equipment for the Allies, found little market for its equipment upon the termination of hostilities. Viewing the formation and growth of the Radio Corp. with anxiety, the officials of this archrival of the General Electric Co. decided that it would be necessary for them to enter the transoceanic radio communication field lest they fall far behind in the industry.

To provide a company for this purpose, they decided to purchase and reorganize the International Radio Telegraph Co. The stock of this company, successor to the National Electric Signaling Co., was owned by the estate of T. H. Given. Given, prior to his death, had bought the interests of Walker, his partner in the earlier company. The International Co. owned, among other patent rights, the heterodyne method of reception and the rotary spark gap. It had remained solvent during the war but was, at this time, in a precarious condition.

On 22 May 1920 the Westinghouse Co. entered into contract with the International Radio Telegraph Co. and its stockholders, Martha A. Given, her daughter, and three others, which provided for the formation of The International Radio Telegraph Co.[31] This new company was organized in June 1920.[32] Under the agreement, the stockholders of the old company were to receive 12,500 shares of preferred stock, par value of $1,250,000, and 125,000 shares of no par value of the new company. The Westinghouse Co. was to purchase a like number of shares of no par value for $2,50,000. In addition to this, the Given beneficiaries retained numerous assets of the original company, including cash and bonds on hand and receivable, and all claims against governments and individuals for patent infringements. By the sale of stock to the Westinghouse Co., they realized a clear profit of $1,250,000.[33] The Westinghouse Co. was indeed desperate.

On 29 June these two companies executed a license agreement wherein the Westinghouse Co. was given the right to manufacture, use, and sell apparatus covered by the patents of the latter except that apparatus for public commercial radio communication purposes could only be sold to The International Co.[34]

Following the incorporation of the new company its president, Mr. Samuel M. Kintner, sailed for Europe for the purpose of executing traffic exchange agreements with foreign radio organizations. To his chagrin he discovered that Young had already assured the Radio Corp. a virtual monopoly in transatlantic communication.

This was a serious setback for officials of

[30] Report of the Federal Trade Commission of the Radio Industry, op. cit., p. 21.

[31] The only change in the name of the new company was the prefixation of the word "The."

[32] Report of the Federal Trade Commission on the Radio Industry, op. cit., pp. 151–154.

[33] Ibid.

[34] Ibid., pp. 157–162.

the Westinghouse Co. Their only possible chance of success in the long-distance radio communication field would be to amalgamate with the Federal Telegraph Co. which possessed a concession with the Government of China for the construction and operation of four stations for interior and one for external communications. In such a combine they would be limited to oriental and transpacific communications but would be in competition with the Radio Corp. which operated a circuit with Japan. In Central and South America the Federal Co. and the Radio Corp. were already joined in the Pan-American Co. The Federal Co. was very desirous of the amalgamation but the Westinghouse Co. officials deemed the field too restricted.

WESTINGHOUSE STRENGTHENS ITS PATENT POSITION

The position of the Radio Corp. was much stronger than that of its rival. The alternator was a far better transmitting device than the rotary spark gap upon which Westinghouse was dependent. This was realized even before the Pittsburgh officials learned of the failure of Kinter's mission. They decided to increase their patent holdings.

The International Co. first sought a cross-license agreement with the Government and this was signed on 5 August 1920. It did not grant The International Co. exclusive use of the Government-owned patents nor was the license transferable. The Government gained, in exchange, the incontestable right to utilize the heterodyne method of reception.

On 5 October 1920 the Westinghouse Co. obtained from Armstrong and Pupin a 30-day option on 4 patents and 16 applications for patents relating to radio. One of these, the Armstrong feedback circuit, was in litigation with De Forest. On 4 November this option was exercised at a cost of $335,000. An additional $100,000 was to be paid if the interference claim was decided in favor of Armstrong.[35] The International Company was cross-licensed to use these patents. As a consequence of this, the Navy also obtained rights under these patents.

WESTINGHOUSE CO. AND GENERAL ELECTRIC CO. BECOME CORPORATE PARTNERS IN THE RADIO CORP.

The rights to the Armstrong and Pupin patents strengthened the position of The International Co. greatly. Westinghouse Co. officials, feeling themselves in a most advantageous position to enter the Radio Corp. as a strong corporate partner of the General Electric Co., directed The International Co. to make overtures to the Radio Corp. Young discussed the proposed agreement between the Radio Corp. and the Westinghouse Co. with Hooper. The latter, still of the opinion that a monopoly was necessary, suggested Young obtain the official concurrence of the Government. He agreed to do this, but the promise was still unredeemed when, on 30 June 1921, Westinghouse joined the Radio Corp.[36] The sales agreement, whereby The International Co. was purchased by the Radio Corp. and a cross-license agreement between Westinghouse and the Radio Corp. in which The International Radio Corp. merger was ratified, was drawn up on that date but was not formally ratified until 8 August 1921. This agreement resulted in a further cross-license agreement being executed between the Westinghouse Co., the Telephone Co., and the Western Electric Co. on 30 June 1921.[37]

The strong patent position of the Westinghouse interests, and the anxiety of the General Electric Co. and the Radio Corp.

[35] Ibid., pp. 170–174.

[36] Hooper briefing of Senator Elihu Root, 21 December, files, Bureau of Engineering, National Archives, Washington, D.C.

[37] Report of the Federal Trade Commission on the Radio Industry, op. cit., pp. 162–199.

concerning this, is indicated by the favorable partnership position achieved by the former. The International Co. stockholders received 1 million shares of both preferred and common stock of the Radio Corp. and retained the $2,200,000 owed the company by the Westinghouse Co. under the 21 June 1920 agreement. The manufacturing of radio equipment, for which the Radio Corp. became exclusive U.S. sales agent, was divided with 60 percent going to the General Electric Co., and 40 percent to the Westinghouse Co.

EXPANSION OF THE RADIO CORP. DURING 1921

On 19 February 1921 the General Electric Co. acquired from the United Fruit Co. one-half the stock of the Wireless Specialty Apparatus Co. On 7 March limited cross-license agreements were executed between the General Electric Co., the Radio Corp., the United Fruit Co., and the Wireless Specialty Apparatus Co. By these agreements the Radio Corp. gained control of the patents of the Wireless Specialty Apparatus Co., including important patents assigned it by Pickard.

On 1 August a traffic aggreement was concluded with the Government of Poland. This was followed by the successful negotiation of traffic and cross-license agreements with the Government of Germany and the German Trans-radio and Telefunken Cos. The last of these agreements was executed on 22 October 1921. On 26 October a traffic agreement was completed between the Radio Corp. and the two French operating companies. At this time, Hooper was inspecting the Lafayette radio station prior to its being turned over to the Government of France. At the instigation of the State Department he was directed to assist the Radio Corp. in their negotiations and was instrumental in convincing the French authorities of the necessity of dealing with the corporation to obtain an American station for the establishment of a transatlantic circuit.[38]

In October 1915 the Marconi Wireless Telegraph Co. of America had requested diplomatic assistance in an effort to extend its facilities to certain South American countries. This aid was denied because of the company's foreign affiliation. On 4 November 1915 the American Marconi officials stated that their attempts to obtain concessions in these countries were entirely independent of any other country and again requested assistance of the State Department. This was again denied. Hooper made the acceptable suggestion of the formation of an entirely new company to exploit radio communications with the South American republics. With the consent of the State and Navy Departments, the Pan-American Co. was formed in 1917. During the organization of the company both the State and Navy Departments were consulted and their solicitors had assisted in drafting, correcting, and amending its charter. Three-eighths of the stock of the company was owned by American Marconi, three-eighths by British Marconi and one-quarter by the Federal Telegraph Co. of California, which was to supply the arc transmitters. Prior to the company's obtaining the necessary concessions from South American governments, the U.S. Government purchased the patents and assets of the Federal Co. with the exception of its holdings in the Pan-American Co.

In early 1918 Nally, President of the Pan-American Co., consulted with LeClair, of the Radio Division of the Bureau of Steam Engineering, relative to proceeding with the Pan-American plans. On 6 February, he wrote the Navy Department a lengthy letter stating the policies and plans of his company and received assurances that Secretary Daniels understood and would not interfere with his plans as presented. Following this, Nally sailed to South America and completed necessary arrangements with the Argentine Government.

[38] Bureau of Engineering, Monthly Report on Radio and Sound, November, 1921.

Upon his return he learned that the Government looked upon the Pan-American plan with disfavor and that Secretary Daniels was determined upon Government ownership of all commercial radio stations in the United States. Appealed to in person, the Secretary stated emphatically that he would not favor the erection of stations by Pan-American, and renounced having discussed or approved such a plan. Nally was informed by Todd, Director of Naval Communications, also an advocate of Government ownership, that the proposed station then about to be constructed at Munroe, N.C., for war communications with Europe, would be used for peacetime communications with South America. Nally was advised that he might well proceed to erect a station in the Argentine to communicate with this station rather than with one owned by Pan-American. He refused to consider this and took no further action in the matter.

When Secretary Daniels deferred obtaining a government charter for the Radio Corp., he promised the officials of the General Electric Co. that the Federal Telegraph Co. would not be permitted to construct arc transmitters for commercial purposes until a final decision had been reached.[39] In compliance with this promise, the Federal Co. was advised that they could not construct transmitters for the Pan-American Co.

At the time the Radio Corp. absorbed the American Marconi Co. and obtained its holdings in the Pan-American Co., no further action had been initiated to establish South American circuits. Shortly thereafter Young came to Washington to confer with Hooper concerning this situation. Following the war, France and Germany obtained radio concessions from the Argentine. These concessions brought about a probability of unhealthy competition or the possible elimination of American interests, as there would be insufficient traffic from any country to warrant more than one station in each.

Hooper and Bullard agreed that the best solution was to form one company which would include companies in all countries holding concessions in South America at that time. The Navy Department gave its sanction to the plan to establish this consortium consisting of the Radio Corp. of America, British Marconi, the Campagnie Général de Télégraphie and Téléphonies (France), and the Telefunken Co. (German).

In conferences between the officials of these companies, an international company was formed, known as the A.E.F.G. with the four companies as equal partners. Each provided two members of the directorate but a neutral chairman, an American, had the power to exercise his veto whenever, in his opinion, any decisions were contemplated which would have been unfair to a minority. In this agreement the Radio Corp. not only achieved a position as an equal partner of the older established companies but, through the power of veto, it actually gained control of the consortium. By a cross-license agreement made at the same time, it obtained the use, in the United States, of the patents of the French company.[40]

THE NAVY OBJECTS TO THE RADIO CORP.'S EFFORTS TO ESTABLISH A MONOPOLY OF SHIP-SHORE COMMUNICATIONS

The proposed Government charter for the Radio Corp. had envisioned that it would be granted a monopoly of long-distance radio communications and, additionally, that it would be a patent holding agency which would freely grant licenses to reputa-

[39] "Radioana," op. cit., letter, dated 30 June 1919, from A. G. Davis to O. D Young, files, R.C.A.

[40] License and traffic agreements—Radio corporation of America, Compagnie Générale de Télégraphie Sans Fil, Gesellschaft Fuer Drahtlose Telegraphie, m.b.h., Marconi's Wireless Telegraph Co. (Ltd,). dated 14 Oct. 1921.

ble manufacturers, thereby stimulating healthy competition.

Despite the concern of many interested Navy officials, excluding Hooper, many of the former officials of the American Marconi Co. were appointed to policy and managerial positions in the new company.[41] These officials brought with them the imbued belief that only the Marconi Cos. and those which succeeded them had legal rights in the radio field. Further, they were not in agreement with the restriction against manufacture imposed upon the Radio Corp.

In reviewing the vacuum tube manufacturing situation existent in the United States at the time of the formation of the Radio Corp., it will be remembered that it was legally impossible, except by agreement between patent holders, for anyone to manufacture the three-element tube. This tube had been manufactured during the war under Government immunity. Following the termination of the war, the Government could no longer assume the responsibility for infringement. The Radio Corp. then entered into an agreement with De Forest to manufacture them under the limited rights he had retained in his sale to the Telephone Co.

In an effort to alleviate the situation, Hepburn, as Acting Chief of the Bureau of Steam Engineering, on 5 Januray 1920, addressed similar letters to the General Electric and the American Telephone & Telegraph Cos. pointing out that, although numerous conferences had been held in connection with the patent situation, nothing of practical value had evolved. The letters ended with a plea for an immediate remedy of the situation.

The General Electric and the Telephone Cos. entered into the previously mentioned agreement on 1 July 1920 which was extended on the same date to include the Western Electric Co. and the Radio Corp. By this the General Electric Co. became for over 2 years the sole legal American manufacturer of the three-element tube for public sale.[42] The existing manufacturing agreement with De Forest was discontinued, thus giving the Radio Corp a sales monopoly of this item.

To the surprise of naval officials who had fostered the agreement, the Radio Corp. refused to sell tubes to competing communications operating companies or to shipowners who did not lease or buy their equipment or utilize their radio maintenance service. This situation continued through the remaining months of 1920 and caused Hooper to address a personal letter to Young, under the date 11 December 1920, in which he stated that all the efforts of the General Electric, Western Electric, and Telephone Cos. to serve the Government and the American people in the radio field were being thwarted by several persons in the Radio Corp. who were determined to exercise a monopoly of radio apparatus.

Young replied to this on 13 January 1921 stating that, in his opinion, Hooper was expecting too much in too short a time and asked his patience and cooperation in his effort to develop an esprit de corps within the Radio Corp. organization and an understanding of the necessity of cooperation with all Government agencies.

The exchange of correspondence continued with Hooper replying on 17 January. This letter contained pertinent remarks concerning three matters of the corporation's policy. The first concerned the sale of three-element electronic tubes. He considered the policy should allow their unrestricted sale, believing that what the Radio Corp. might lose in competition in the ship-shore business could be offset by sale of tubes and by increased good will. He further stated that the corporation should be able to keep ahead of its competitors for the merchant marine business by constantly providing better equipments and

[41] "Radioana," op. cit., SRM 5–672, files, R.C.A. Young advised Hooper in December 1919 that many Navy officials had criticized him for this action.

[42] License agreement between the General Electric Co. and the American Telephone & Telegraph Co. datd 1 July 1220.

services. The second matter dealt with the erection of coastal stations. He stated that Sarnoff and others, without knowledge or in disregard of agreements, had shifted back to the same old Marconi idea of a complete chain of commercial coastal stations. These were to be supported by the receipts obtained by a monopoly on ships' installations which they hoped to attain by restrictions on the sale of tubes. He followed this by the statement, "Such a policy must inevitably lead to the Department's withdrawal from any agreements now observed by the Government." Continuing, he advocated the encouraging of two strong competing companies in the ship-shore business, operating under agreed upon and sane policies, one of which should permit shipowners free choice in contracting for installations. He ended this with the statement that the personnel of the Radio Corp. seemed to be against permitting such competition. The final comment referred to a growing tendency of the corporation's personnel to dictate to the Navy what it must or must not have in the details of equipment, and stated that cooperation was not as good as it had been before the Radio Corp. came into existence. Hooper's papers do not contain a reply from Young concerning these remarks.

On 25 April 1921 the Chief of the Bureau of Engineering again addressed similar letters to both the General Electric and the Telephone Cos. criticizing them for failure to provide ships of the merchant marine with tubes unless the owners contracted for service or purchased or leased equipment from the Radio Corp. Indirectly replying to this, the Radio Corp. attempted to tighten its monopoly by implied threats of legal action against commercial users of tubes in equipments not provided by them.

At a meeting of the directors of the Radio Corp. on 21 April 1922, it was agreed that licenses should be granted to companies manufacturing equipment for the U.S. Government provided such equipment was not used for toll purposes. At the same meeting it was decided to sell complete installations or parts thereof to shipowners or agents and to competing radio companies operating ship radio service with the following restrictions:

> Licensed only for use on board merchant ships and merchant aircraft for radio telegraphic and radio telephonic communications destined to or originating on board such ship or aircraft; or for relaying radio telegraphic or radio telephonic communications between ships at sea and aircraft, between ship and aircraft and shore and vice versa.[43]

Authorization was granted to lease competing companies transmitting apparatus of 2 kw. or less antenna input and receivers for installation in shore stations for ship-shore and shore-ship communications purposes only. The royalty to be charged for this equipment was to be based on the percentage of gross business for which the apparatus was utilized. In the event that shipowners and competing companies refused to accept these imposed conditions and continued the corporation's alleged infringement of its patents they were to be placed on formal notice and, in due course, prosecuted.[44] This new policy was partially publicized in the August 1922 issue of World Wide Wireless which contains the statement that the Radio Corp., "responding to the call of humanitarianism for the first time permitted the use of its vacuum tubes on competing ship stations."

The Independent Wireless Telegraph Co. refused to accept the imposed conditions. On 7 November 1922 the Fleming patent on the two-element expired. De Forest legally began the manufacture and sale of tubes under rights of manufacture and sale to amateurs retained by him when he sold his triode patents to the Telephone Co. He sold tubes to the Independent Co. On 6 April 1923 the Radio Corp. filed suit against the Independent Co. and named De Forest as a coplaintiff. De Forest refused to appear. The court held that the patent

[43] Report of the Federal Trade Commission on the Radio Industry, op. cit., p. 70.

[44] Ibid., p. 71.

owner must voluntarily join as plaintiff and would not consider the suit.[45]

The "radio boom" of 1922 caught the Radio Corp. and its associated companies unprepared. Complete sets were soon demanded by the public. The corporation could not meet the demand. Numerous companies entered the field, some without knowledge of the existent patent situation. One hundred thousand receivers were sold in 1922. In 1923 550,000 were purchased and the demand was steadily increasing.[46] The Radio Corp. unsuccessfully endeavored to control the situation by filing infringement suits against manufacturers providing sets which contained base receptacles which would accommodate tubes manufactured for amateurs. The Radio Corp.'s court actions and its failure to grant licenses to reputable manufacturers created public resentment which Congress recognized by the adoption of House Resolution 548 which directed the Federal Trade Commission to submit a study of the radio industry.

The necessity for properly exercised control of the numerous radio patents is well recognized. Had the Radio Corp. followed the concept of Young and provided equitable licensing to reputable manufacturers, as they later did in 1927, they would have performed a meritorious service to their Government and to the people of the United States. Instead, they pursued the same tactics as the old Marconi Co. and, in so doing, they cost their stockholders and the public millions of dollars, which swelled only the coffers of various patent law firms and a few selfish individuals.

THE NAVY SUPPORTS THE FEDERAL TELEGRAPH CO. IN ITS ENDEAVORS TO ESTABLISH TRANSPACIFIC RADIO CIRCUITS

On 8 January 1921 the Federal Telegraph Co. entered into an agreement with the Republic of China wherein that company was to erect and operate one station for transpacific communications and four stations within China for interior communications. Previous to the granting of this concession, the several preceding Chinese Governments had granted concessions to Danish, Russian, and British-Japanese communication companies. During 1921 these concessions became the subject of diplomatic negotiations among the Government of China and the governments of all countries holding concessions.[47]

One of the requirements of the contract between the Chinese Government and the Federal Co. required the latter to own the patents for all equipment to be installed. At this time these were owned by the United States with the Navy Department as custodian. The State Department, in furtherance of U.S. interests, requested that these patents be returned to the Federal Co. This was done, with the Government retaining a nonexclusive, nonrevocable, and nontransferable license to use existing and future Federal patents.

Young, fresh from his conquest of South American communications, objected to this, feeling that the Radio Corp. should be free from competition in the United States in the international radio communication field. In view of the several concessions granted by China, he suggested a consortium similar to the one established to handle South American communications.[48]

On 12 December 1921 he addressed a letter to Senator Elihu Root, one of the four U.S. delegates to the Washington Disarmament Conference, that stated that if the consortium was not desirable, the Federal Co. should be supported in the construction of the Chinese stations, and that the United States end of Chinese-American transpacific circuit should be owned by the Radio Corp. This letter was referred to the Navy Department together with a copy of

[45] Ibid., p. 91.

[46] Broadcasting Yearbook, 1946, p. 20.

[47] "Radioana," op. cit., letter, dated 7 Dec. 1921, from Owen D Young to James R. Sheffield, files, R.C.A.

[48] Ibid.

a letter to Mr. Sheffield, attorney for the Radio Corp.,[49] suggesting the establishment of a consortium.

The Secretary of the Navy, the Hon. Edwin Denby, replied to the Secretary of State on 16 December 1921, giving general approval to Young's plan, provided the approvals of the several governments were obtained, and provided that a monopoly of transpacific communications would not be established in the United States.[50]

Senator Root, on 21 December, requested the Navy to provide an oral briefing on the subject. This was given on that date by Capt. S. W. Bryant, USN, Assistant Director of Naval Communications and Hooper, who had been appointed Technical Advisor in Radio Matters to the senior U.S. delegate to the Disarmament Conference. During this briefing the history of the radio situation in the United States from 1904 to that time was first presented by Bryant. Then Hooper commented upon the existent issue. The following pertinent portions of his comments are synopsized from a memorandum [51] written by him immediately following the meeting:

> Monopoly is a very bad thing, as it restricts the development of the art, the sale of apparatus at reasonable prices in competition to the public, and service to ships. The Radio Corporation has a strong monopoly everywhere except in the Far East, and anything this conference does to increase its strength may result in serious harm to this country.
>
> The Federal Telegraph Company of San Francisco, about a year ago, negotiated a very excellent contract with the Chinese Government. The Navy Department, at the request of the State Department, transferred the patents of the Federal Telegraph Company back to them in order that they could carry out their part of the contract with the Chinese Government. This is a very good arrangement for American business and the State Department supports it. Since the Westinghouse Company has joined the Radio Corporation the only competition possible seems to be between the Federal Company and the Radio Corporation as regards long-distance communication. Since competition is necessary, the Federal Company should establish itself in China and no arrangement should be encouraged between the Radio Corporation and the Japanese company or any such combination which will lessen the chances of success of the Federal Company.
>
> The Federal Company will watch the American interests in China better than the Radio Corporation because the Radio Corporation covers a world-wide field and naturally cannot give particular attention to one locality. The Federal Company should have stations on the west coasts of the United States and South America and in the Far East and the Radio Corporation should cover the rest of the field. This would permit ideal competition in the manufacture and sale of apparatus, and stimulate the activities of both companies.

In this memorandum Hooper wrote that Senator Root, in substance, stated that his sole interest was to protect China from various parties who were endeavoring to get concessions through bribery and misrepresentation of their personal interests, and that he could see that a monopoly was endeavoring to get him to take an interest in something which should more properly be considered by the executive departments and that, therefore, he would forward the correspondence to the Secretary of State as a matter of more direct concern to him.

On 22 December Young addressed a six-page letter [52] to the Secretary of the Navy commenting upon the reservations made in the letter to the Secretary of State of 16 December. The tenor of his letter indicates that he was thoroughly disturbed by the Secretary's position. He stated that in regard to the first reservation:

> . . . I am entirely in accord with its spirit and purpose. My only hesitation is a practical one. Confusion, misunderstanding and delay usually result from an attempt of the representatives of several governments to act in unison on any program.

Continuing, he disavowed any knowledge as to which department of our Government was authorized to act exclusively in the radio field, stating that several departments were attempting to deal with it and that their policies were not uniform and were often conflicting.

In commenting upon the second reservation he stated:

[49] "Radioana," op. cit., files, R.C.A.

[50] Files, Secretary of the Navy, National Archives, Washington, D.C.

[51] Files, Bureau of Engineering, National Archives, Washington, D.C.

[52] Files, Bureau of Engineering, National Archives, Washington, D.C.

. . . I am prepared as a result of my own experience and after careful consideration to maintain the proposition that competitive radio stations in the United States for international communication is in the interest of the foreigner and to the detriment of America.

He deplored the fact that Congress had failed to enact legislation preventing foreign interests from establishing radio stations in the United States and that, if such stations were established, foreign governments could dictate the terms under which our radio communications would be carried on. He then reitterated his belief that competition should be between radio and cables and that the Radio Corp. should have an exclusive U.S. monopoly for international radio communications.

In late December the Secretary of the Navy responded to Mr. Young. This letter [53] stated that President Roosevelt had, in 1904, designated the Navy as the department responsible for Government policy in national radio matters. He sharply stated that if the Radio Corp. chose to go elsewhere for advice without consulting the Navy and to take actions contrary to the opinions of officers of that service it would reap the results of such action. After stating the Navy's beliefs and policies [54] he closed thanking Young for his views and suggesting that he might be able to work up some plan which would not possess the objectionable features of an international pool.

On 9 January 1922 Young wrote the Secretary of State, again requesting that the question of an international consortium be considered for handling Chinese radio communications be added to the agenda of the Disarmament Conference. This letter [55] was referred to Senator Root who, on 11 January, replied stating that it was beyond the scope of the Conference to handle the subject and that it should be taken care of through diplomatic channels.

Hooper, on 3 June 1922, wrote Young commenting upon the actions taken by the Radio Corp. In this he stated: that events of the last year had shown that his advice was correct about the tube, and the Chinese and Westinghouse situations and, had this advice been followed by the Radio Corp., it would have had a happier path and would not have the public against it. Continuing, he wrote that insofar as China is concerned, he would never recommend approving any compromise on the proposition that communication between the United States and China was solely a matter be-

[53] Ibid.

[54] Navy policies concerning radio as stated by the Secretary of the Navy: "It is advisable to keep radio in competition with cables at the present time but in order to do this, it is not desirable to hold up an international pact, of such character that, should cables eventually be replaced entirely by radio, there would be no competing radio companies.

"International arrangements for American stations to communicate with foreign stations are necessary and desirable, but exclusive contracts can only result in an international pool, which, directly or indirectly, will result in submerging the interests of each country with the others in the group, and in building up a situation which in the years to come, may not be in the best interest of the United States.

"The interests of any of the governments must be compromised in any international monopolistic combination, with those of the other governments, and which ever government is most efficient and agressive for the moment gains important advantages over the others. This is not in the best interests of the strategical situation, in event of war, and after all, the security in event of war is most important.

"An international pool, or even a pool in any one country, is directly or indirectly restrictive of competition in sales of material, ship service, and in the advance of art.

"Where competition is undesirable because of the lack of traffic, and radio competition with the cables, it might be preferable to temporarily divide the radio field among different radio companies, say one company to operate in the Pacific, and another in the Atlantic, and still a third independently in South America. This at least would give competition in the material features of radio, and, later on, if the cables should become less important and competition becomes desirable across each ocean, it could grow naturally, by the intrusion of these various companies in the others' temporary field.

"It is essential that provision be made by which foreigners cannot be licensed to build radio stations in the United States."

[55] "Radioana," op. cit., files, R.C.A.

tween the two countries. If the United States disapproved of any other policy, the Radio Corp. was perfectly safe because no foreign interest would be granted a permanent operating license to communicate with the United States unless approved by the U.S. Government.[56]

On 6 June 1922 Young made a conciliatory reply praising Hooper for his inspiring influence in the organization of the Radio Corp. and commented:

> I do think we are making progress on the international situation helpful to America. What you say is quite true, that progress might have been made in other ways, and very likely more advantageously. Certainly, I should not wish to say that the steps taken in the order taken have been one hundred percent wise. The most one can hope for is to get along with the best judgement he has and with the use of such material, human and otherwise, as is available. If one's judgement were always right and men could be found who were one hundred percent perfect to execute it, that would, of course, be not only comfortable but an ideal situation.[57]

While this tempest was brewing, the position of the Chinese Government deteriorated to such an extent that it was feared that a Chinese bond issue, which was to be floated in the United States to finance the construction of the stations, would lack sufficient subscribers. The Federal Co. was also in a precarious financial position. These circumstances, combined with Young's realization that the Government would not consider a consortium, made it necessary for the two companies to take concerted action. On 8 September 1922 they formed the Federal Telegraph Co. of Delaware for the purpose of constructing and operating the Chinese stations. Seventy percent of the stock of this company was owned by the Radio Corp., and the remainder by the Federal Telegraph Co. of California. The U.S. terminal of the transpacific circuit was to be a station of the Radio Corp. This partnership was approved by the Chinese Minister of Communications on 13 July 1923, thereby eliminating all other parties concerned insofar as Chinese-American radio communications were concerned. However, the dilatory actions of the Chinese Government delayed and discouraged action for years.

[56] Ibid.

[57] Ibid.

EPILOG

With the advent of the broadcasting boom, radio became a household necessity and the commercial use of this medium far outstripped the military uses. Government policy, making for its control, rapidly became more and more within the province of the Department of Commerce. Later the Federal Communications Commission was established by Congress to control the civilian use of the medium.

CHAPTER XXXI

The Navy and the Patent Situation

EARLY PATENT DISPUTES

The advent of radio in the United States was accompanied by a patent dispute.[1] Such disputes were to continue for more than a quarter of a century and, combined with the stock manipulations engineered to force rivals from the radio communication field, did much to deter the growth of the new communication medium. The Navy, the largest single American user of radio during this period, immediately felt the impact of these disputes and manipulations and was forced to evolve policies to cope with the situations.

The Marconi interests, feeling that only they had legal rights in the field of radio communciation, established a policy of leasing equipment and providing Marconi-controlled operators to shipowners. One of the clauses of the standard contract included a prohibition against intercommunication with ships or stations fitted with equipment not owned by the Marconi interests. In this manner they hoped they could eliminate competition and establish a worldwide monopoly without the necessity of resorting to expensive and uncertain litigation.

In December 1899 the Navy Department was informed by the newly formed American Marconi Wireless Telegraph Co. that Marconi equipment would not be sold to the Navy. In lieu of outright sale, they proposed the standard lease. This offer was immediately and positively rejected. After the failure of negotiations with Marconi, the Navy Department procured and installed Slaby-Arco equipments of German manufacture in many of its major ships and shore stations during 1903. This action was the cause of considerable criticism by the Marconi and National Electric Signaling companies.

About the time the foreign equipments were delivered, several American companies entered the field and commenced the manufacture and sale of radio equipment equally as good or better than that which could be purchased abroad. The Navy Department, not desirous of being dependent upon a foreign country for supplies which might become unavailable during war, adopted the policy of supporting these manufacturers to the fullest extent possible. This increased the clamors and claims of the Marconi and Fessenden interests to such an extent that the Navy was forced to include a proviso in all radio apparatus procurement contracts requiring supplying contractors to defend the Government against infringement suits which might be brought against it because of its use of the purchased apparatus. This contract clause, combined with a limited market, resulted

[1] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., SRM 137–009.

Upon Marconi's first arrival in this country in September 1899, he was informed by Prof. Amos Dolbear, of Tufts College, holder of basic patents covering an induction system of communications, that he would be restrained from using his system in this country. Later, as a matter of courtesy, Dolbear agreed to take no action to prevent the radio reporting of the International Yacht races. However, after the Marconi Wireless Telegraph Co. of America was incorporated, the professor instituted legal action, which he later withdrew when he became convinced that Marconi's methods were not covered by his patents.

in constant demands by contractors for the elimination of certain specifications in order either to avoid patent suits or better to fit their own manufacturing capabilities without incurring expensive retooling costs.

The Navy Department was constantly plagued by interests claiming basic patents. The National Electric Co. claimed, among numerous other things, the patent rights on the use of the 500-cycle note and the electrolytic detector. The first was later to be held invalid on proof that Woberton and other naval personnel had modified the Slaby-Arco equipment to utilize it prior to Fessenden's patent application. The Marconi Co. quickly protested the sale of any equipment which they considered infringing the four-circuit tuning patent or the utilization of inductive coupling. Considering the many claims, no firm could possibly meet Navy specifications without facing the possibility of patent litigation.

In 1906 the Marconi interests modified their sales policies and entered bids for Navy contracts. At this time small quantities of equipments were purchased from the Marconi, Fessenden, Stone, Massie, Shoemaker, and De Forest companies. In 1908 the Navy commenced procurement of most of its receivers from the Wireless Specialty Apparatus Co. which held the unassailable Pickard patents.

EARLY U.S. NAVY PATENT POLICY

In May 1910 the Navy promulgated two statements of policy: (1) That only such patents as had been established as valid by the highest courts of the United States could be considered as adjudicated; and (2) the liability for supplying the Navy any device protected by patent must be borne by the contractor. The first printed specifications for radio equipment contained the following clause:

> The contractor shall protect, defend, and save harmless the Navy Department against any demand for patent fees or other claims of any description for any patented invention, article or arrangement that may be used in the construction or form any part of the articles delivered under the contract of the methods nesessitated by their use.[2]

A few months later Congress enacted legislation, approved 25 June 1910, which contained the proviso:

> That whenever any invention described in and covered by a patent of the United States shall hereafter be used by the United States without license of the owner thereof or lawful right to use the same, such owner may recover reasonable compensation for such use by suit in the Court of Claims.

The unsatisfactory situation caused Todd, Head of the Radio Division of the Bureau of Steam Engineering, to write John Firth, of the Wireless Specialty Apparatus Co., on 11 December 1911:

> The Bureau cannot take cognizance of patents. We must have certain apparatus and we must go on buying it from whomever can or will supply it until we are informed by the Department of Justice or some other authority that we must stop it.[3]

By 1913, procurement of radio equipment was limited to seven firms, many of whom provided only specific items; e.g., the Wireless Specialty Apparatus Co. sold receivers and accessories but remained out of the transmitter field because of lack of basic patents; the Radio Telephone & Telegraph Co. provided only amplifiers and associated equipment; the Federal Telegraph Co. built arc transmitters, but their position in the receiver field was unsatisfactory; Fritz Lowenstein and the Atlantic Communications Co. (Telefunken) provided quenched-spark transmitters. With the exception of the Atlantic Communication Co., none of these firms could or would provide equipment to meet naval specifications. Under the existing international situation it was not deemed advisable to purchase equipment from foreign sources; therefore, purchases from that firm were made only in cases of necessity. Marconi

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[2] Naval Specification 16 T 5, p. 31, par. 114–10, May 1910, files, Bureau of Equipment, National Archives, Washington, D.C.

[3] "Radioana," op. cit., files, Wireless Specialty Apparatus Co.

equipment had undergone little basic improvement in design or circuitry over the decade and was considered by most engineers to be obsolescent. Research had been performed under the supervision of Marconi in England, but he had been more inclined toward the improvement of his existent system than to the development of a better one. The American Marconi Co. had operated under a deficit until 1911 and was not in the position to finance costly research. In 1912 the National Electric Signaling Co. discharged Fessenden, who by that time had developed the heterodyne method of reception, but had achieved no success in developing a satisfactory high-power means of generating continuous waves.

According to George H. Clark, senior naval expert radio aid:

> There was much dissatisfaction in naval circles with the commercial receivers which were still its standard. For one thing, the thin-wire connections from apparatus to binding posts were constantly breaking off due to vibration of destroyer, or submarine and despite specifications, despite personal please, American manufacturers would not adopt the stiff solid-wire leads which navy men required. (This is not true of Telefunken receivers; their leads were made according to best military standards.) Again, the variable tuning condensers supplied did not stand up under vibration, under heavy handling; the plates were too thin, too close together, and short-circuits and changes of calibration were common. Still a third objection; the coils used in these receivers were of high resistance, which meant that the receivers would not buckle down to the job of receiving one station and eliminating all others of slightly different time. Dr. Austin had pointed the way toward the design of low-loss coils but commercial manufacturing standards apparently did not permit of using these. So in the early part of 1913 the Bureau began to consider designing and building its own receiving instruments.[4]

NAVY PLANS TO DESIGN AND MANUFACTURE RADIO EQUIPMENT FOR ITS OWN USE

Finally, it was decided early in 1913 that the Navy would proceed, design and manufacture radio equipment for its own use. From the patent standpoint the Navy was in no different position than any other contractor and the Marconi and other interests would have been quick to claim infringement of their basic patents. At this time Dr. Louis Cohen, famed for his work with Dr. Austin in developing the empirical formula for the determination of signal strength at specific distance from transmitting source, completed the development of a receiver utilizing a new method of coupling, using condensers instead of inductance coils. In February 1913 the Bureau of Steam Engineering obtained rights from Cohen and procured his services to assist in the designs of receivers.

Receiver designs were completed prior to February 1915 but, during the interim, many things occurred which improved radio reception, among them the development of the three-element tube as an oscillator and amplifier and the feedback circuit as a means of controlling oscillations. The heterodyne method of reception became more feasible because better regulation of this circuit could be obtained by use of the feedback circuit. The use of the three-element tube in stage amplifiers provided better means of bringing in weak signals. All of these developments were incorporated in the naval receiver designs and the utilization of some of these were definite infringements. The increased requirements for radio equipment, brought about by the preparedness program and our later entry into the war, were too large for naval manufacturing facilities, and necessitated continued contracting with commercial manufacturing concerns for equipments based on naval designs.

WARTIME PATENT PROBLEMS

In September 1915 the Marconi Wireless Telegraph Co. of America sought an injunction against Emil J. Simon, claiming he was supplying the Navy with equipment which they claimed infringed the four-

[4] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 96.

circuit tuning patent. Simon's defense, based on the act of 5 June 1910 and the "right of eminent domain," claimed that the owners of any patents involved were limited to the recovery of damages from the United States. His contentions were sustained by Judge Hough, presiding over the U.S. District Court for the Southern District of New York. This decision was upheld by the U.S. Circuit Court of Appeals for the Second Circuit. As a result of this, the military departments were able to intensify their defense preparations, and manufacturers, believing themselves secure from litigation, began to supply apparatus based on naval design and specifications.

For a year there was comparative quiet in this battle of radio patents when, suddenly, the storm broke. In September 1916 a decision was rendered in favor of the complainants in the suits brought about by *American Marconi* vs. *De Forest*, wherein the complainant claimed infringement of the Fleming two-element tube, and in the countersuit whereby De Forest, as complainant, claimed infringement of his three-element tube. Neither Marconi nor De Forest nor any other company could legally manufacture the badly needed three-element tube without the mutual consent of the two interested companies.

On 4 March 1918 the Supreme Court reversed the decision previously rendered in the above-mentioned *Marconi* vs. *Simon* case. This decision of the High Court held the manufacturers liable for infringements and, by this time, there had been many, including numerous new manufacturers who had, at the Navy's request, supplied infringing apparatus. The Navy Department found itself confronted by the threats of the manufacturers to cease production unless some way could be found to afford them protection. As a result, on 29 March 1918, Acting Secretary of the Navy Franklin D. Roosevelt addressed the so-called "Farragut letter" to the De Forest Co. accepting certain responsibilities on the part of the Government for the protection of patent claims and, on 3 April 1918, he advised the Bureau of Supplies and Accounts that similar letters would be sent to other contractors when and if such action appeared to be necessary.[5]

Following the failure, in 1915, of the Marconi interests to procure the Alexanderson alternator, an unconfirmed statement was made by the representatives of the Federal Telegraph Co., who were anxious to sell their stations, that the Marconi interests were endeavoring to purchase their stations and patent rights. They stated that they considered it their patriotic duty to inform the Navy prior to entering negotiations with the Marconi interests. In order to protect American national and naval interests the Navy purchased the Federal stations and patents for $1,600,000 on 15 May 1918.

Upon the entry of the United States in World War I, the Alien Enemy Property Custodian seized all German-owned radio patents issued by the United States. These patents were purchased for the Government by the Navy Department.

As a result of these actions the Government, at the end of World War I, was in possession of a considerable number of patents. Many of these were of little value, but among them were valuable patent rights such as those on the Poulsen arc transmitter and the Meissner feedback circuit. Rights over this circuit were in four-way battle between the Government; the General Electric Co., which owned Langmuir's claim; the American Telephone & Telegraph Co., which had purchased the De Forest patent in 1917; and Edwin Armstrong, who at that time still retained his patent rights. This legal struggle was not finally settled until 1934 when the Supreme Court of the United States decided in favor of De Forest. Additionally, the Navy was licensed under the Cohen coupling patent and the Hazeltine neutrodyne circuits.

[5] Hearings before the Military Affairs Committee, House of Representatives, 67th Cong., 1st sess., 1921, "Settlement of Claims Against the United States Government for Use of Radio Patents During World War I" (Washington, Government Printing Office, 1921).

Congress, by an act approved 1 July 1918, reiterated the intentions contained in the invalidated act of 25 June 1910, and legalized the action of the Acting Secretary of the Navy. This act stated:

Whenever an invention described in and covered by a patent of the United States shall hereafter be used or manufactured by or for the United States without license of the owners thereof or lawful right to use the same, such owners' remedy shall be by suit against the United States in the Court of Claims for the recovery of his reasonable and entire compensation for such use and manufacture.

POSTWAR DETERMINATION OF RADIO PATENT INFRINGEMENTS BY THE GOVERNMENT

In compliance with the spirit of this legislation, and in an effort to avoid multiple compensations for infringements by various departments, the Government established the Munitions Patent Board to determine its liabilities. Because of the highly complex and confused situation existing in the radio patent field, the Government additionally established the Interdepartmental Radio Board to hear radio patent claims and to make recommendations for settlement.

The members of this Board were Comdr. S. C. Hooper and Lt. Comdr. Edwin H. Loftin, USN, representing the Navy Department; Capt. Guy H. Hill, USA,; Mr. Robert H. Young, representing the War Department; and Mr. Harry E. Knight, representing the Department of Juctice.[6] Loftin was elected Chairman, and his entire duties for over 2 years were devoted to the work of this Board. In this he was principally assisted by Mr. Knight.

The Board made a complete study of the diversified patents, with Loftin passing upon technical considerations and Knight upon the legal aspects.[7] Fourteen hundred contracts covering the period from 29 July 1910 to 1 January 1920 were examined.[8] These contracts included apparatus manufactured by commercial firms and by the Government, and also included parts purchased to modernize old equipments or to assemble new ones. Two-thirds of the apparatus under consideration had been purchased or manufactured by the Navy. Ninety percent of the equipment had been purchased since 1916, and much of it was still in its original cratings. All the claims were considered for adjudicated patents, while only those considered valid in view of the prior art were considered in the case of unadjudicated ones.[9]

The work done by the board, and more particularly by its Chairman, involved a tremendous amount of detail. It called for the equivalent of a detailed examination of the entire radio patent situation in the United States and to some extent abroad; it required decisions as to whether a specific invention was general in character and hence involved operation of the entire system, or whether it could be replaced without material loss or effect; it had to consider several prior decisions of the Court of Claims, from which an idea of 'fair amount of royalty' could be obtained; it paid careful attention to commercial practice in these matters as to fair royalty payments; finally it had to determine the life and usefulness of each specific apparatus. This last factor, however, proved unsolvable; the criterion finally established was to recommend award on the basis of purchase price alone, independent of the time and actuality of use.[10]

The following firms either submitted no claims or stated they had none:

American Radio & Research Corp.
Cooper Hewitt Electrical Co.
Cutting & Washington
Federal Telegraph Co.
General Radio Co.
Kilbourne & Clark Manufacturing Co.
Liberty Electric Corp.
Wireless Improvement Co.
Stone Telegraph & Telephone Co.

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[6] Report of Interdepartmental Radio Board; orders dated 12 Feb. 1921; files, Bureau of Engineering, National Archives, Washington, D.C.

[7] Testimony of E. H. Loftin before War Claims Arbiter, docket 778, *Telefunken* vs. *U.S.*

[8] "Radioana," op. cit., report of J. J. Cosgrove, of Sheffield & Betts, to the Radio Corp. of America re Interdepartmental Radio Board accounting, SRM 100–420.

[9] Report of the Interdepartmental Radio Board, op. cit.

[10] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 366; Cosgrove report, SRM 100–420.

Seven firms submitted claims totaling $14,860,000 and 17 others demanded monetary awards without fixing the amounts of their claims.

The number of patents considered was greatly reduced due to the zeal, tact, and integrity of Loftin. The Marconi Co. originally submitted a list containing 350 patents which they considered infringed, but they reduced this to 4 upon obtaining a clear idea of the Board's fair and impartial method of evaluation.[11] Other companies also reduced the numbers they had submitted as infringed, so that the final number of patents considered was 209.[12]

The total cost of radio apparatus purchased by the Government during the period of accounting covered by the board amounted to $40,425,404.36.[13]

The Interdepartmental Radio Board report, dated 31 May 1921,[14] was addressed to the Secretaries of War and Navy and to the Attorney General of the United States and recommended awards totaling $2,869,-700.27, divided among the following:

Marconi Wireless Telegraph Co. of America	$1,253,389.02
International Radio Telegraph Co. (National Electric Signaling Co.)	711,451.85
American Telephone & Telegraph Co.	615,333.57
E. H. Armstrong	89,624.74
H. M. Horton	75,000.00
E. J. Simon	30,273.31
Lowenstein Radio Co.	22,892.80
Wireless Specialty Apparatus Co.	22,449.69
Dubilier Condenser Co.	18,194.31
John Firth	15,560.93
National Electric Supply Co.	8,875.00
Sperry Gyroscope Co.	5,000.00
Louis Cohen	1,271.25
American Mechanical Improvement Co.	383.80

Of the total, $1,819,520.69 was apportioned to the Navy Department and the remainder to the War Department.

The Wireless Specialty Apparatus Co. disregarded the recommendations of the Board and brought suit in the U.S. Court of Claims, averring a claim of $6 million. The case was dropped.[15] The claims of the American Telephone & Telegraph Co. and the Dubilier Condenser Co. were repeased to the Government under special agreements. Maj. Harry Horton, USA (retired), received a special grant of $75,000 for the infringement of his patent on the use of a trailing wire as an antenna for aircraft.[16]

Two House resolutions (Nos. 6501 and 7111) were introduced in the 1st session of the 67th Congress to authorize payments as adjudicated. Congress, feeling that such matters were rightfully within the province of the Court of Claims, tabled both bills. The work of the Board, although not carried through to the end for which it was established, did do much to prove the sincerity of the Executive Branch of our Government in its efforts to discharge indebtedness incurred at a time when the personal rights of a few necessarily were subjugated to the necessities of war. Practically all claims were eventually settled by the Government through due processes of the Court of Claims.

POSTWAR PATENT PROBLEMS

Following the termination of hostilities the patent situation was so confused that no manufacturer could safely sell his equipment for either amateur or commercial purposes. Military requirements were virtually nonexistent, as large quantities of surplus apparatus were on hand. Armstrong declared, in testimony taken by the Federal Trade Commission:

> It was absolutely impossible to manufacture any kind of workable apparatus without using practically all the inventions which were then known.[17]

[11] Loftin testimony, docket 778.

[12] Interdepartmental Radio Board report, op. cit.

[13] Ibid.

[14] Files, Bureau of Engineering, National Archives, Washington, D.C.

[15] Loftin testimony, docket 778.

[16] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 367.

[17] W. Rupert Maclaurin, "Invention and Innovation in the Radio Industry" (Macmillan Co. New York, 1949), p. 99.

In 1919, Loftin stated:

That there was not a single company among those making radio sets for the Navy which possessed basic patents sufficient to enable them to supply without infringement . . . a complete transmitter or receiver.[18]

The situation was of vital concern to the Navy. Although the surplus equipment was available, it was rapidly becoming obsolescent. New equipment soon would be required to modernize the radio installations as all indications pointed to the possibility of electronic transmitters becoming available early in the future.

On 3 January 1920 the Acting Chief of the Bureau of Steam Engineering, Rear Adm. A. J. Hepburn, USN, addressed similar letters[19] to the American Telephone & Telegraph & Co. and the General Electric Co. with a copy to the Western Electric Co. These letters stated in part:

Referring to numerous recent conferences in connection with the radio patent situation and particulary that phase involving vacuum tubes, the Bureau has consistently held the point of view that all interests will be best served through some agreement between the several holders of pertinent patents whereby the market can be freely supplied with tubes, and has endeavored to point this out with concrete examples for practical consideration.

In this connection the Bureau wishes to invite your attention to the recent tendency of the Merchant Marine to adopt continuous wave apparatus in their ship installations, the Bureau itself having arranged for equipping many vessels of the Shipping Board with arc sets. Such installations will create a demand for vacuum tubes in receivers, and this Bureau believes it particularly desirable, especially from a point of view of safety at sea, that all ships be able to procure without difficulty vacuum tubes, these being the only satisfactory detectors for continuous waves.

Today, ships are cruising on the high seas with only continuous wave transmitting equipment except for short ranges when interrupted continuous waves are used. Due to the peculiar patent conditions which have prevented the marketing of tubes to the public, such vessels are not able to communicate with greatest efficiency except with shore, and therefore, in cases of distress it inevitably follows that the lives of crews and passengers are imperiled beyond reasonable necessity.

In the past the reasons for desiring some arrangement have been largely because of monetary consideration. Now, the situation has become such that it is a public necessity that such arrangement be made without further delay, and this letter may be considered as an appeal, for the good of the public, for a remedy to the situation.

It is hoped this additional information will have its weight in bringing about a speedy understanding in the patent situation which the Bureau considers so desirable.

In anticipation of the signing of a satisfactory cross-licensing agreement by the General Electric Co. and the American Telephone & Telegraph Co., the Bureau of Steam Engineering on 14 January 1920 addressed the following letter[20] to the Radio Corp., the Western Electric Co., the Westinghouse Electric & Manufacturing Co., the De Forest Radio Telephone & Telegraph Co., and the American Radio & Research Corp.:

In the present transition from the use of spark radio transmitters to the use of continuous wave transmitters, it is a well-established fact that apparatus of the vacuum tube type is far more desirable, from most points of consideration, then apparatus of the arc type. The maintenance cost of tube equipment, however, is at present prohibitive, due largely to the high cost of tubes.

The annual maintenance cost for a low-power (2-kw. input) arc transmitter is $100.00, whereas for a tube set of equal power input, this cost is $1,000.00. It is, therefore, evident that the introduction of tube apparatus into the service must await, except in exceptional cases, the very material reduction in the price of transmitting tubes.

The Bureau will extend all of its facilities to the end of assisting in this price reduction. A very definite standardization policy is being formulated which should also be of material assistance in this regard.

On January 20, 1920, the Bureau will forward an outline of the proposed standardization policy. On Friday, January 30, 1920, there will be held at the Bureau a conference at which suggestions and comments from manufacturers will be heard and the matter generally discussed. It is requested that you be represented at this conference.

THE RADIO CORP.'S USE OF PATENTS TO ENFORCE MONOPOLY

By early 1921, as a result of mergers and cross-licensing agreements, the Radio Corp.

[18] "Radioana," op. cit., SRM 100.

[19] Files, Bureau of Engineering, National Archives, Washington, D.C.

[20] Ibid.

either owned or possessed license rights to use more than 2,000 patents. These included the most important patents of the time and provided the Radio Corp. and its affiliated companies with a monopoly in the manufacture and sale of radio equipment. This permitted the Radio Corp. to control the sale of apparatus for commercial radio communication purposes.[21]

The Radio Corp. utilized its patent position in controlling commercial radio communications and in forcing shipowners to lease or purchase RCA equipment and to seek RCA assistance for maintenance. With the companies not associated with the Radio Corp. holding insufficient patents to legally manufacture radio equipment, it was not possible for the Government to obtain the modern equipment it required through the usual process of competitive bidding. The situation engendered the growing distrust of Navy officials in this company it had sincerely fostered.

The agreement made between the General Electric and American Telephone & Telegraph Cos. on 1 July 1920 permitted the former company and its licenses the unrestricted right to manufacture the three-element tube.[22] These tubes could only be sold through the Radio Corp. which, despite pleas of naval officials, they refused to sell to companies in competition with them in the merchant marine radio field.

On 25 April 1921 the Chief of the Bureau of Engineering again addressed similar letters[23] to the General Electric and Telephone Cos., reiterating the statements contained in his letter of 3 January 1920, and criticizing both companies for failing to supply the merchant-marine market with tubes excepting in those ships having contracts with the Radio Corp. He closed his letter with this paragraph:

> It is feared that unless the market is supplied with the necessary tubes to equip ships at least, the existing agreement may take on the appearance of furthering a monopoly rather than breaking it.

The situation remained unaltered until about August 1922 when, as reported by the issue of World-Wide Wireless of that month, the Radio Corp. "responding to the call of humanitarianism for the first time permitted the use of its vacuum tubes on competing ship stations." However, the restrictions on the use of the vacuum were very stringent and no competing company which accepted the terms could long survive.

Competition did exist, however, in the sale of receiving sets, complete except for tubes, particularly from the seventeen firms Armstrong had licensed prior to the sale of his feedback patent to the Westinghouse Electric & Manufacturing Co. The Radio Corp. considered the manufacture and sale of the receivers for use with separately purchased "amateur-use only" vacuum tubes to be an infrinegment on its tube patents. In an endeavor to test the validity of their contentions, in May 1923 they brought suit against A. H. Grebe Co. Inc., one of the Armstrong licensees, claiming infringement. The significance of this suit was unquestionable. Radio publications joined the hue and cry raised by the public against the Radio Corp. Congressional investigation ensued, and House Resolution 548 directed the Federal Trade Commission to investigate and report upon the status of the radio industry in the United States. The findings of the Commission ultimately brought about a satisfactory licensing program but, for over half an important decade, the development of radio had been slowed by the patent policy of the largest manufacturers.

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21 "Report of the Federal Trade Commission on the Radio Industry" (Washington, Government Printing Office, 1924), p. 69.

22 License agreement, General Electric Co. and American Telephone & Telegraph Co., dated 1 July 1920.

23 Files, Bureau of Engineering, National Archives, Washington, D.C.

CHAPTER XXXII

The Development of Fleet Tactical Communications

FLEET COMMUNICATIONS SITUATION AT THE END OF WORLD WAR I

The development of radio in the Navy had been based on its use over long distances as an extension of telegraph and cable facilities and as a means of communication with and between ships at sea. The naval situation during World War I was such that little change was required in this concept. With the exception of the 6th Battle Squadron, the operations of our ships consisted of protecting our convoys from and taking offensive action against German submarines. A single tactical circuit normally sufficed each of the separate units engaged in these operations and, for most purposes, the newly developed radiotelephone set (CW 936) was used.

The primary wartime tasks of the Naval Communication System were the provision of long-distance radio facilities to provide communications between the United States and Europe and the broadcast of meteorological and hydrographic information and intelligence to our units at sea. The secondary task was the provision of the very limited tactical communication requirements of the convoys and hunter-killer groups. When the war ended the Naval Communication System was the largest most efficient, and best equipped radio communication facility in the world. On the other hand, when the ships were reassembled into fleets, there was but little improvement in fleet tactical communications over that which existed at the beginning of the war, although there had been considerable improvement in both receiving and transmitting equipment.[1]

Following the war there was the normal period of relaxation of effort. At that time Secretary Daniels, concerned about the existent situation, stated, "The danger to every navy after a great war, indeed, the national tendency, if history is any test, is for fleets to become stale." [2] The economic and military results of a too-rapid demobilization caused disruption, disorganization, and loss of millions of dollars of equipment.[3] For the better part of a year little was done to improve fleet communications.

THE IMPROVEMENT PERIOD

Following the war, several studies were conducted to determine the best organization of our naval forces to meet the changing concepts of naval warfare occasioned by our emergence from World War I as a world power, and the development of aircraft as an integral arm of the service. From these studies there eventually evolved a plan for the consolidation of the Atlantic and Pacific Fleets into a single fleet, subdivided into the scouting and battle fleets, and the control and base forces.

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[1] The 10 Jan. 1925 issue of the Washington (D.C.) Star quoted the Chief of the Bureau of Engineering as stating that the radio equipment in naval vessels was estimated to be worth $7,500,000.

[2] Annual Report of the Secretary of the Navy, 1919 (Washington, Government Printing Office, 1919), p. 10.

[3] These lessons learned from World War I were quickly forgotten, and the same conditions recurred at the end of World War II.

The Bureau of Engineering and the Office of the Director of Naval Communications followed the trend of these studies and obtained the opinions of higher naval officers which early indicated the strong possibility that the major fleets would be consolidated under a single command. In consonance with the trend and these opinions, a fleet communication plan [4] was jointly developed by these two offices during late 1919. Essentially, the plan provided duplex circuits between:

Navy Department and Commander in Chief; Commander in Chief, fleet and force commanders, and all ships; force commanders and the immediate subordinate commanders such as squadron, flotilla, or division depending upon force organization; flotilla or squadron commanders and division commanders; and division commanders and commanding officers of ships of their divisions.

In order to implement this plan, all ships would require additional receiving facilities to cover the Commander in Chief's circuit and the shore stations broadcasts of time, weather, and hydrographic information. Since some forces were still equipped with spark equipment, together with the necessary damped-wave receiving equipment, it would be necessary for the Commander in Chief to transmit simultaneously to his force commanders on both damped and undamped waves and, likewise, to receive both types of emissions. One or the other of the Commander in Chief's frequencies would have to be guarded constantly by designated ships of each force, usually by the force flagships. In the event that parts of a force was separated geographically, guard ships would be required for each area. Additional circuits would be.required for each area. Additional circuits would be required for the purposes of exchanging gunfire-control information and for communications between battleships and their observation planes.

As simple as this plan appears under present-day operations, it was far in advance of equipment and installation capabilities. Before it could be used with any degree of success, ships would have to be fitted with transmitters emitting within very narrow bands, designed to make it possible to reduce power to the minimum required, and with sharply tunable receivers capable of rejecting undesired signals. The transmitters would also need to be equipped with "break keys" which would stop other transmitting to permit the uninterfered reception of important messages. Even after these things were accomplished, completely successful operation would require the maximum possible separation between the transmitters and receivers in each ship, as well as means of multiple transmission and reception to reduce the number of antennas.[5]

Some of these requirements could not be met immediately. Satisfactory vacuum tube transmitters were not available to replace the arc and spark sets. The reinstallation and separation of transmitters and receivers required major overhauls and, before the transmitters could be placed belowdeck and behind armor in the battleships, experimentation was necessary to determine the size and type of antenna trunks.

The Bureau adopted the models E, F, and R receiving systems as temporary standard installations. To improve selectivity, to reduce interference, and to permit the use of two receivers on one antenna, the complicated and temperamental acceptor-rejector circuits of the Royal Navy were included as parts of the E and F systems. The motor-buzzer set was adopted as a substitute for the spark gap for low-powered communications.

Immediate steps were taken to intensify research directed toward the development of satisfactory systems for the multiple use of transmitting and receiving antennas and for the elimination of arc-transmitter compensating and harmonic frequencies and mush. Experimentation was commenced in the U.S.S. *Ohio* to determine the optimum belowdecks installation of transmitters and the best type and minimum size of antenna

[4] This plan was titled "The Force Tune System."

[5] Bureau of Engineering Monthly Report of Radio and Sound, November 1919.

trunks. Commercial interests were requested to improve vacuum tubes and to develop higher powered ones for transmitting purpose. In order to encourage the research and development of tube transmitters, contracts for 45 low-powered ones (5, 150, and 750 watts output) were given the General Electric and Western Electric Cos.[6]

PREPARATIONS FOR FORMING A SINGLE FLEET

The implementation of the decision to form a single fleet was held in abeyance while the Washington Disarmament Conference was being held because the international political repercussions of such an action might well have had adverse effects upon the deliberations of the conferees. The obsolete U.S.S. *Seattle* had been designated to become the flagship of the U.S. Fleet and was being readied for this service. The statutory limitation on the amount that could be spent for this purpose prevented duplexing the radio equipment. However, separate transmitting and receiving rooms were fitted out. These were given the maximum possible separation.[7]

Meanwhile, the fleet frequency plan was tested in both the Atlantic and Pacific Fleets during the combined exercises of these fleets held during the winter of 1921–22. The commanders of both fleets submitted lengthy reports on the operations and reliability of communications during the exercises and, although these were somewhat at variance, both considered their communications entirely unsatisfactory as to personnel and material. When used, the fleet frequency plan caused so much interference that it was impossible to receive messages. The principal reasons for the failure were the absence of duplexing; the interaction of antennas; the broad signals emitted by the spark transmitters; the compensating and harmonic frequencies and the mush emitted by the arc; and the almost complete lack of personnel capable of or interested in endeavoring to make such a plan work.[8] The models TB and TC vacuum tube transmitters that had been installed in the battleships prior to these exercises proved entirely unreliable.[9]

Before it was realized that models TB and TC were unsatisfactory, contracts had been signed for the production of models TE, TF, and TG. The contract for the latter was cancelled. The Model TE transmitters were installed on submarines and, although not completely satisfactory, were an improvement over the small spark sets previously installed in this type of vessel. The Model TF, similar to the Model TE, but not configured for fitting into submarines, was installed in submarine tenders and cruisers and also was an improvement over the previous equipment. Ships equipped with either of these transmitters and with the Model RA receiver had the best and most reliable ship radio communications in the Navy in 1922.

RADIO COMMUNICATIONS SITUATION IN THE U.S. FLEET

Following the Senate's ratifications of the terms of the Disarmament Conference, a new "U.S. Naval Policy" was prepared by the General Board of the Navy. This was approved and promulgated by the Secretary of the Navy on 29 March 1922. That portion of the policy relating to communications is quoted below:

> To maintain and operate a naval communication system based on the requirements of the forces afloat in a campaign in either or both oceans.
>
> To provide and operate radio compass stations as required.

[6] Supra, ch. XXVIII.

[7] Memorandum, dated 18 July 1924, from Fleet Radio Officer to Fleet Material Officer.

[8] Letter, dated 24 Apr. 1922, from Commander in Chief, Pacific Fleet, to the Chief of Naval Operations.

[9] Supra, Ch. XXVIII.

To develop within the Fleet the uses of all forms of communications required for battle efficiency.

To provide adequate radio communications facilities to mariners along the United States coasts where private facilities are more available.

On 1 July 1922 the U.S. Fleet Organization was put into effect. Adm. Hilliary P. Jones, USN, was appointed Commander in Chief, U.S. Fleet, and he chose Lt. T. A. M. Craven,[10] USN, as his Fleet Radio Officer.

During the winter of 1922–23 the first fleet exercise was held in waters adjacent to Panama. In his report dated 14 March 1923, the Commander in Chief made the following statement:

"The Commander-in-Chief considers that rapid communication within the fleet, between the fleet and its bases and between the fleet and the Navy Department is neither satisfactory nor reliable. The maneuvers of the United States Fleet off Panama during both 1922 and 1923 have demonstrated this fact in the most profound manner; and although there has been some improvement during the past two years, the Commander-in-Chief believes that the subject of communications still warrants the serious and immediate consideration of the Department."

This report contained specific recommendations as to the communication requirements of the fleet and means of satisfying them. It also made the recommendation that communications be made a part of the battle efficiency competition in order to increase the interest of commanding officers in this facet of operations. When this recommendation reached the Navy Department it created a furor. Couched in terms which unmistakenly warned that it was impossible for the fleet to operate as a united force in battle unless communications could be improved to meet requirements, immediate action was forthcoming. During May and June the members of the General Board studied the report and held extensive hearings on the subject. Their recommendations, concurring with the Commander in Chief, were submitted to the Secretary of the Navy, who approved them.

On 1 July 1923 Adm. R. E. Coontz, USN, became Commander in Chief, U.S. Fleet, and Hooper was assigned duty as Fleet Radio Officer. Capt. R. W. McNeely, USN, relieved him as the Head of the Radio Division, Bureau of Engineering. Craven was ordered to the Bureau of Engineering and assigned duty as Head of the Ship Section of the Radio Division.

EFFECTS OF RADIO BROADCASTING

While the above was transpiring, the radio broadcast boom hit the United States. On 1 January 1922 there were eight licensed radio broadcasting stations in the United States. By 1 May they had increased to 279 [11] and, by the end of the year, to 569.[12] Each of these stations was licensed to operate on a specific frequency between 500 and 1500 kc. during specified periods of the day. Day by day, the number of stations continued to increase. At the end of 1922 it was estimated that there were between 1½ and 2½ million radio receivers in the country.[13] As the number of stations increased, the interference increased proportionately with the density of stations in a particular area. In locations along the seacoasts, the high-powered arc transmitters and the remaining spark transmitters of the Navy disrupted reception of these stations and, likewise, the broadcasting increased the difficulties in receiving messages transmitted by naval radio. The owners of broadcast receivers far outnumbered the receivers on naval stations. If their hue and cry

[10] Craven was born in Pennsylvania, and was appointed a midshipman from New Jersey. He graduated from the Naval Academy in 1913. In 1930 he resigned from the Navy as a lieutenant commander. He was later appointed to the Federal Communications Commission. After serving one term as a member of that Commission he practiced as a communications consultant in Washington, D.C. He was again appointed a member of the Federal Communications Commission, and is now serving his term.

[11] Radio Service Bulletin, Department of Commerce (Washington, Government Printing Office, 1922), 1 May 1922.

[12] Ibid., 1 Jan. 1923.

[13] Orrin E. Dunlap, Jr., "Radio and Television Almanac" (Harper & Bros., New York, 1951), p. 71.

against the naval radio stations did not reach the heavens it, nonetheless, did reach the ears of high Government officials. The result: much of the money of an already drastically reduced radio budget was expended on improving the emission characteristics of the shore radio stations. This reduced the funds available to improve fleet radio communications. This was not the end. Once aroused, the clamor could not be quieted. In some areas the public could not be convinced that the interference they encountered was from other than naval sources. The Second National Radio Conference was held in Washington in the spring of 1923. Broadcasting interests, abetted by the public, demanded the Navy relinquish the 500–1500-kc. band. The Interdepartmental Radio Advisory Committee [14] acquiesced to this demand and agreed that, as soon as possible, the Navy would use the frequencies within this band only on a noninterference basis.[15] The broadcast boom was not entirely against the interest of naval communications, for it did provide an increased incentive to the commercial interests to develop improved vacuum tubes, transmitters, and receivers.

IMPROVEMENT OF SHIP INSTALLATIONS

Based upon experiments conducted in the U.S.S. *Ohio* and the recommendations of the Commander in Chief, new standard installation plans for capital ships were formulated. These plans envisaged a communications control center adjacent to the command center. The main receiving room would contain eight receivers for the following purposes:

1 low frequency (12–150 kc):
Shore communications.

3 medium frequency (75–1000 kc):
Commander in chief, force comanders, and for long-range communications.

4 High frequency (1500–4000 kc):
Officer in tactical command, division commanders, gunnery control observers, and spotting planes.

Multicoupling, using a tube coupling system devised by Taylor and Young, was to be installed so that all eight receivers might use the same antenna simultaneously.[16] The receivers would be remotely connected to the communications control center or the conning tower and copied at those locations. The main transmitting room, which was to contain four transmitters, was to be located below the first deck, and, in the battleships, it was to be behind the armor belt. The primary transmitter, an arc equipped with the Eaton Uniwave key and transformer coupling, would cover the frequency rance 75–550 kc. A tube transmitter, of lower power, would cover the same range. The other two were to be tube transmitters covering the range 1500–4000 kc. The master oscillator power amplifier control system was to be used to provide the necessary frequency stabilization. One of the higher frequency transmitters was to be capable of being voice-modulated. The plan required that all four transmitters could be used simultaneously and could be keyed from the bridge, conning tower, or by the operator at any of the receiving positions. Three emergency receivers were to be installed in a screened, soundproof booth in the transmitter room.[17]

In providing the equipment for this installation, the Bureau took into account the agreement to vacate the broadcast band except on a noninterference basis. The Commander in Chief's comments on this plan are contained in a letter dated 27 March 1924. He did not agree in adopting a policy of vacating the frequencies which the fleet had used for years without assur-

[14] This Committee was established within the Executive Branch of the Government to advise the President on radio matters effecting Government usage.

[15] Personal letter, dated 18 July 1924, from Hooper to the Director of Naval Communications.

[16] Supra, ch. XXVIII

[17] Bureau of Engineering monthly, Radio and Sound Report, July 1924.

ance that the new frequencies would be satisfactory and that sufficient funds would be available to provide equipments using those frequencies. He warned that as soon as the Navy developed the frequencies above 2000 kc. and perfected its apparatus, private or other Government interests would insist upon another shift. Commenting further upon vacating the broadcast band, he stated that in his opinion the number of broadcast stations would be greatly reduced in the future and it would then be possible to arrange for the use of alternate blocks of frequencies within this band and for area assignments.[18] He closed his letter recommending that, since it would take years to develop service above 3000 kc., apparatus should be provided the fleet for using the band between 800–2100 kc. and that separate receiving rooms should not be considered until after service trial in some fleet units.[19]

This letter reflected the opinions of Hooper, who at that time saw little future in radio broadcasting. In a personal letter to the Director of Naval Communications, dated 15 July 1924, he commented that fleet personnel had a feeling that possibly the Department and the fleet were assuming a great deal more worry and work than was necessary because the existence of a temporary situation in radio broadcasting. In defense of this position he opined that the number of long-distance radio broadcasting stations was greatly in excess of what it would be in a few years that these stations would be reduced in a short time from the hundreds then in existence to perhaps 2, and that these would be owned by the Telephone Co. and Radio Corp.

In early 1923 the first of the Navy-designed alternating current tube sets, Model TL, was installed in the U.S.S. *Wyoming* for service tests and proved to be very satisfactory.[20] Models TM, TN, and TO, utilizing spark transmitter components, were quickly developed. The Model TM was used to replace the 500-watt spark sets on submarines not fitted with Model TE. Model TN, 6 kw., was installed in shore stations. Model TO, 100 watts, voice-modulated, was built for installation in battleships for intrafleet communications. The CW 936 transceiver, installed on all ships, was modified to transmit interrupted continuous waves for use in intrafleet communications to replace the motor-buzzer sets.

During 1923 all battleships were equipped with TL transmitters. Some were also provided with TO transmitters. The U.S.S. *California* radio installation was modernized and duplexed to some extent. The U.S.S. *Colorado* and U.S.S. *West Virginia*, then building, were completely duplexed during their construction. Other capital ships which followed them were also completely duplexed.

CONTINUED UNSATISFACTORY TACTICAL RADIO PERFORMANCE

During January and February 1924 the fleet exercised, conducting Fleet Problems II, III, and IV. While these were being held Hooper wrote that the TL set was working fine and was being used for almost everything, and that the TO was also working very nicely. Despite Hooper's favorable comments on the radio transmitters, communications during the exercises were not satisfactory. It was difficult to get the ships to use their assigned frequencies which often resulted in delays of from 2 to 5 hours in obtaining acknowledgment of a message. Such unsatisfactory performances did not gain the confidence of the commanders.[21]

On 16 February, Commander, Battleships Divisions, Battle Fleet, appointed a board to investigate the deficiencies of radio communications within his command. On 23 February Rear Adm. L. M. Nulton, USN,

[18] Ibid., August 1924.

[19] Ibid., September 1924.

[20] Ibid., March 1923.

[21] Personal letter, dated 29 Jan. 1924, from Hooper to McNeely.

the senior member, reported the findings of the board. These were sharply critical of communications operations within the fleet and more so of the state of readiness of radio material. In substance, the board rendered the following opinions:

Too much is being attempted with too little by poorly qualified personnel.

The Fleet Communications Plan cannot be carried out with the diversified, incongruous radio installations existent within the fleet during this period of transition from spark apparatus, with its broad emission, to sharply tunable equipment. Theory is far ahead of material improvements. Destroyers have obsolete apparatus. Cruisers have excellent long-distance equipment, but that for short distance is not satisfactory. Sharply tunable receivers have not been installed in any of our ships.

Existing regulations require a uniformity and versatiltiy of procedure beyond which the equipment is capable. This results in confusion and discouragement of personnel. Additional confusion is caused by absence of authority.

An impracticable number of communication channels are now required. It should suffice that:

Unit commanders be able to communicate with the units of their commands and their immediate seniors in the chain of command.

The Commander in Chief be able to communicate with his immediate subordinate commanders and with the Navy Department.

In closing its report the Board made the following specific recommendations:

Permit free and absolute control by the division commander over radio within a division. Require that specific equipment be assigned and be limited to this function with higher authority making no other use of it whatever, either for communications or drills.

Require that all communication drills be held at specified times and be of specific duration.

Require a continuous watch on not more than two frequencies on any one ship.

Following the completion of the exercises, the Commander in Chief's report was submitted to the Chief of Naval Operations. It contained the following comments:

Radio equipment, particularly receiving equipment, is not up to date.

The absence of forward receiving rooms in nearly all flagships, aircraft carriers, and aircraft tenders prevents duplex operation. This includes such ships as the U.S.S. *Omaha, Richmond, Savannah*, and *Procyon*.

There are no sharply tunable receivers in the fleet.

There are few sharply tunable transmitters and more are needed to free ships from interference when working simultaneously.

Loading coils should be added to the Model TL tube transmitter to permit use of low frequency so that the use of arc sets be made unnecessary as these preclude duplex communication.

Some means of reducing transmission range to approximately known distances is required.

Devices for changing frequencies are not satisfactory. In operations when a ship goes from one task force to another it should be possible to shift frequency accurately by setting a dial. It would usually be impossible to send test messages to tune in as is now necessary. Flaghips should be equipped first.

Base force flagships, tenders, and repair ships should be equipped for low-power continuous-wave intrafleet communications to permit them to handle, without interference, the continuous large volume of traffic incident to the performance of their mission.

Destroyer squadron flagboats require long-range tube transmitters with provision for reducing their power for short-range work. The four units contracted for with the General Electric Co. are suitable for trial and can be installed by forces afloat prior to 1 November 1924.[22]

Notwithstanding the approved recommendation of the Navy General Board and the continued demands from the Fleet for improved equipments, the Bureau of Engineering was faced with difficulties in carrying out its radio modernization plans. In addition to curtailed appropriations, legal and administrative problems continued to confront the Bureau. The problem was complicated by a statutory limitation on the amount that could be expended on the navy yard overhaul of a ship as well as the prerogatives of its commanding officer and of the commandant of the overhauling yard as governed by Navy Department instructions. The determination of how the money was to be expended was causing difficulty. With the concurrence of the Commander in Chief, the Bureau had planned to duplex the radio installation of the U.S.S. *Arizona* during the navy yard overhaul of that ship in early 1924. But the project received such a low priority that it was not accomplished.

The failure to duplex the *Arizona*

[22] Personal letter, dated 19 Feb. 1924, from Hooper to McNeely.

caused Craven, Head of the Ship Section of the Radio Division, to recommend to his superior, McNeely, that the Commander in Chief list the radio projects he desired accomplished and request funds be set aside for them for no other purpose. On 18 June, McNeely, in a personal letter to Hooper, quoted Craven's recommendation. Tempers began to flare. In a tersely worded reply, dated 27 June, Hooper intimated that the Bureau of Engineering, and especially the Radio Division, was attempting to evade its responsibilities. He pointed out that it was not the province of the commander to tell a Bureau how to allocate its money as this was, by law, a function of each bureau.

He continued by advising McNeely of the manner in which he accomplished the work of the Radio Division when he was its head, and closed with the following quoted paragraph:

> To come down to brass tacks, we have made our recommendations, and we have made a summary of what we think you will do this year, based on our previous ability to obtain a proper proportion of Bureau money and our ability to buy, test and install. We expect you to produce. We would appreciate a systematic method of keeping informed as to progress on the projects in order to make certain necessary arrangements.

A less kindly officer than McNeely might have demanded redress for the statements and tenor of this letter. Except for one other letter, written by Hooper on the day following, Hooper's papers contain no record of further personal correspondence between these two officers.

Under the existing appropriation system, established by law, funds were appropriated to the several bureaus of the Navy Department and the chief of each of these was responsible for their expenditure. The Secretary of the Navy recognized the inadequacies of the appropriation system. In his annual report for 1928 he recommended that funds for the support, maintenance, repair, and operation of ships of the fleet be appropriated in a lump sum in order that the entire overhaul of each vessel could be properly coordinated and financed.

This situation continued to be a deterring factor in the modernization of radio installations. Necessary and satisfactory belowdeck spaces, always insufficient, were allocated to the various bureaus, and each of these was most reluctant to give up assigned spaces to meet the particular requirements of another. Moreover, the necessary alterations to ships' structures had to be approved by and paid for by the Bureau of Construction and Repair. As might be rightfully expected, radio installations were far down on their priority lists as compared with the upkeep and maintenance of hulls.[23]

Congress, in the 1925 Appropriation Bill, provided the Bureau of Engineering with over \$1½ million which had been requested for the improvement of radio installations in ships.[24] This amount would have been sufficient to modernize the radio installations of all ships in commission. Unfortunately, this matter was not coordinated with the Bureau of Construction and Repair and no specific funds were sought for the purpose by that Bureau. This resulted in only a few of the larger ships being duplexed during that fiscal year.

TREND TOWARD THE USE OF HIGHER FREQUENCIES

The failure to utilize the funds appropriated for 1925 to modernize the fleet installations was not as unfortunate as might be expected. By the end of that year, naval research facilities, assisted by the research activities of amateurs and others, had discovered many of the secrets of shortwave

[23] Years later this unsatisfactory situation was recognized and the Bureau of Engineering and Construction and Repair were consolidated into the Bureau of Ships.

[24] Personal letter, dated 28 June 1924, from Hooper to McNeely.

transmission paths, including "skip distance" and the confirmation of the Kennelly-Heaviside theory.[25] Experiments conducted by the fleet during that year proved the superiority of the 2000–3000-kc. band for tactical communications and demonstrated the reliability of low-powered, long-distance radio communications in the 4000–20,000-kc. band. The future use of these higher frequencies for long-distance ship-to-shore communications would provide a means of reducing the size and weight of transmitting equipment and the size of antenna trunks and watertight deck and bulkhead insulators. During the year, contracts were entered into with the various manufacturing companies for a large number of improved vacuum tube transmitters for intrafleet and long-distance radio communications and for improved types of receivers, the models RE, RF, and RG. Paralleling this development, improved equipment for aircraft utilizing the 3000–4000 kc. band became available. The master oscillator power amplifier method of frequency control was adopted as standard for transmitters used for intrafleet communication. Crystal control was used for transmitters of frequencies above 3000 kc. Air-cooled tubes with plate voltages of less than 5,000 volts, using direct current supplied by motor generators, were utilized for shipboard equipments.

RADIO MODERNIZATION PLAN

Considering the enormous strides made in high-frequency radio communications, the Bureau of Engineering in 1925 decided to modernize all major ship installations during their next overhauls. The Commander in Chief, in his report on the tests of high frequency, recommended:

(a) Equip flagships of fleets and forces with high-frequency equipment for ship-to-shore communication.

(b) Equip all cruisers with high-frequency equipment for long-distance communication, but do not remove arc until new equipment is proved.

(c) Test high frequency for use in submarines and, if successful, assign a specific frequency for submarine intrafleet communications.

(d) Confine shore station transmissions to frequencies less than 9000 kc. because of ship reception difficulties due to internally generated shipboard noises.

(e) Confine shipboard transmissions to frequencies less than 7000 kc. in order that ships within 400 miles of each other may communicate.

(f) Shift to the 2000–3000 kc. band for intrafleet communications.[26]

The Navy Department concurred with the Commander in Chief's recommendations, except those which confined the use to frequencies below 9000 kc. The rejection of this recommendation was based on the need for higher frequencies for daylight use. For fiscal year 1926, Congress was requested to appropriate $550,000 for duplexing 2 battleships and 6 cruisers and for equipping these plus 10 battleships, 9 cruisers, 8 auxiliary vessels, and 19 destroyers with the new transmitters and receivers.[27] This request was coordinated with the Bureau of Construction and Repair.

In September 1925 the Bureau of Engineering issued a statement of its position concerning the radio modernization program. This contained the following pertinent remarks:

An acknowledgment that the radio installations in the fleet were obsolete and fell short of meeting requirements.

The Bureau and the Office of Naval Communications were engaged in formulating a comprehensive naval communications plan which would allocate frequencies in the higher portion of the spectrum for naval usage. Upon approval of this plan by the Interdepartmental Radio Advisory Committee it would form the basis for final designs of new equipments.

Concurrently, both naval and commercial research facilities were conducting research based upon the requirements of this plan. This research was, of

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[25] This theory was based on the belief that the upper portion of the earth's atmosphere contains layers of highly ionized air capable of bending or reflecting radio waves back to the earth. These layers cause fading, skip distance, and variations between day and night reception.

[26] Letter, dated 8 Sept. 1925, Commander in Chief, U.S. Fleet, to the Chief of Naval Operations.

[27] The Washington Star, 10 Jan. 1925.

necessity, slow because of the scarcity of naval radio engineers and the numerous problems confronting the commercial companies in the broadcast field.

Upon completion of designs, the new equipments must be service tested in and approved by the fleet and that undue haste in these tests might cause erroneous conclusions to be drawn which would result in further loss of time and undesirable expenditures of funds.

The program, carried through to its conclusion, would eliminate the unsatisfactory situation within a few years and the fleet would then have a modern electronic communication system capable of meeting initial mobilization requirements and of rapid expansion.[28]

The Naval Communications Frequency Plan [29] was approved by the Interdepartmental Radio Advisory Committee early in 1926. The importance of this plan, which was fundamentally the work of Craven, cannot be overemphasized. Not only did it provide the necessary guidance for the modernization of the Naval Communications System, but with modifications it has lasted throughout the years. More important, it became the basis for the international allocations of frequency bands for specific services established by the Fourth International Radio Conference convened at Washington in 1927. The Convention which stemmed from this Conference was of far-reaching importance because it stabilized the international use of the radiofrequency spectrum and made it possible for all navies and merchant-marine shipping to operate on any part of the high seas without undue interferences.

Craven's plan provided detailed allocations of frequencies for naval usage during both peace and war. Very low frequencies plus frequencies between 4000 and 4525 kc. and the harmonics thereof were assigned naval shore radio stations. The Fleet was assigned a few low frequencies for use of the Commander in Chief, fleet, force and battleship division commanders for long-distance communications; and frequencies between 4000 and 4525 kc. and the harmonics thereof for the same purpose. Frequencies between 2000 and 3000 kc. were assigned for intrafleet tactical purposes. Communications between aircraft and ships were assigned frequencies between 3000 and 4000 kc. Communications between air stations and aircraft were provided by the utilization of some of these same frequencies augmented by the use of the broadcast band frequencies on a noninterference basis.

Once the decision to utilize the higher frequencies was finally made, there were no further major changes in the modernization plan. Battleships, cruisers, aircraft carriers, and tenders were duplexed during their next navy yard overhauls. The harmonic operation of the earlier equipment was far from satisfactory and most of the transmissions were confined to the fundamental frequencies. Later, Lt. Comdr. J. B. Dow, USN, designed an electron-coupled circuit that made the utilization of the harmonics practicable. By the end of 1927, practically all of the arc and spark transmitters had been relegated to museums or to the scrap pile.

In 1924 the design and development of high-speed (100 words per minute) keying and recording mechanisms was completed. These were then manufactured and installed at the shore stations where they greatly increased the traffic-handling capabilities of point-to-point circuits.

During the early 1920's there were many minor improvements in ancillary equipment. Higher dielectric bulkhead and deck insulators were designed and manufactured, as were also insulators of greatly increased tensile strength. Radiocompass equipment for ships was improved, and better locations obtained to increase accuracy.

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[28] Bureau of Engineering Monthly Report of Radio and Sound, September 1925.

[29] App. K.

CHAPTER XXXIII

Postwar Development of the Navy Shore Radio System

PROLOG

World War I had placed an operational requirement upon naval communications which was more in support of the ground than of the naval forces. This is not intended as an implication that fleet communications were considered secondary, for this was not the case. The Navy was the only department of the Government possessing any ability to operate transatlantic communication circuits and, though that was poor at the time we entered the war, it was natural that the responsibility for providing this service be delegated to it. By the time of the cessation of hostilities, transatlantic radio circuits had been greatly improved and could have handled a large portion of the necessary communications between the United States and Europe.

THE POSTWAR SHORE RADIO SYSTEM

The purchase of the Marconi ship, coastal, and Alaskan stations and of the Federal Telegraph Co., combined with the acquisition of the Sayville station from the Alien Property Custodian, left only a few long-distance stations remaining in the ownership of two companies: the Marconi Wireless Telegraph Co. of America and the Tropical Radio Co .

The determined stand of Secretary Daniels on continued Government operation of these stations following the armistice and the efforts of Roosevelt, Bullard, and Hooper to eliminate British domination of radio communications have been related. The efforts of the latter group delayed the return of the leased stations until the Radio Corp. of America could be formed. Therefore, from the armistice until 1 March 1920, when the leased stations were returned to the Tropical Radio Co. and the Radio Corp., the latter of which had come into possession of the American Marconi interests, the Navy continued to conduct all the commercial radio business of the United States in addition to providing radio services for itself and other Government departments.

During the fiscal year of 1920, the commercial earnings of the system were $1,116,593.37. This included the revenue from 84 coastal stations handling ship-shore traffic, the circuits with Norway and Japan for approximately 6 months, and a circuit with Germany for 10 months. This figure does not include the free services rendered other Government departments amounting to approximately $1 million.[1]

Due to rapid demobilization, most of the shore station were operating with about 40 percent of their complements. This condition would have been aggravated had commercial positions been available for radio operators. Bullard had forseen this

[1] Annual Report of the Secretary of the Navy, 1920 (Washington, Government Printing Office, 1920), p. 68.

problem, and this was one of the reasons why he could not support Daniels' struggle for Government ownership.

Naturally, the commercial interests decried Government ownership and operation. They were successful in thwarting Secretary Daniels and, at midnight 29 February 1920, their stations were returned to them for commercial operations controlled by the provisions of Public Law No. 264 of 13 August 1912.

ASSISTANCE PROVIDED THE EMBRYONIC NATIONAL COMMERCIAL RADIO COMPANIES

The commercial companies possessed few coastal stations and were unable to provide satisfactory ship-shore services. In many localities they had not established necessary point-to-point circuits. The provision and operation of these facilities had to be continued by the Naval Communications System. This action was legalized by Congress on 5 June 1920 by Public Resolution No. 48 which, in part, stated that Government stations could be utilized by national newspaper interests and for commercial business for a period of 2 years; provided:

> That the right to use such stations for any of the purposes named . . . shall terminate and cease as between any countries or localities or between any locality and privately operated ships, whenever privately owned and operated stations are capable of meeting the normal communication requirements between such countries or localities or between any locality and privately operated ships, and the Secretary of Commerce shall have notified the Secretary of the Navy thereof . . .

During 1920 the commercial companies established stations at principal U.S. ports to provide ship-shore radio communication facilities. There were numerous locations where the anticipated revenues were not sufficient to interest them, and the Navy continued to provide the required facilities as well as those for isolated localities which required point-to-point radio communications in a volume insufficient to warrant commercial interest. Additionally, Public Law No. 264 prohibited commercial radio operations within the Canal Zone. Many of these circuits were provided by the Naval Communication System on a scheduled basis.

Although the Radio Corp. expedited the expansion of its international circuits, the services were not totally sufficient, therefore, on 14 April 1922 the authority granted by Public Resolution No. 48 of 5 June 1920 was extended until 30 June 1925.[2]

During this period of 5 years the provision of ship-shore facilities and the operation of the U.S. terminals of the below-listed circuits provided commercial revenue amounting to over $1,500,000:

Tutuila	Apia, British Samoa.
	Papeete, Tahiti.
Cavite	Hanoi, French Indochina.
	Malabar, Dutch East Indies.
Balboa	Puerto Barrios, Guatemala.
	Tegucigalpa, Honduras.
	Limón, Costa Rica.
	Bluefields, Nicaragua.
	Managua, Nicaragua.
	Bragman's Bluff, Nicaragua.
	Cape Gracias, Nicaragua.
	Swan Island.
	Belize, British Honduras.
	Santa Marto, Colombia.
San Juan	Curacao.
	St. Kitts.
	Martinique.
Port-au-Prince	Santo Domingo.
Guantanamo	Kingston, Jamaica.
St. Thomas	Curacao.

In 1924 the commerical companies commenced the use of higher frequencies which allowed coverage of larger ocean areas by their coastal stations, and from that time there was a gradual diminution of the assistance needed from naval radio stations.

SERVICES RENDERED MARINERS

In addition to radio direction-finder services rendered all mariners upon request, broadcasts of information relative to safe

[2] Public Res. No. 48 of 14 Apr. 1922.

navigation were made by specific stations at specified times. These included broadcasts of time signals, hydrographic notices, meteorological reports, weather forecasts, storm warnings, and obstruction reports. Time signals were broadcast by all high-power and some intermediate-power stations twice daily in an effort to provide this service on a worldwide basis. Broadcasts of other information were provided on a regional basis as necessary. Broadcast schedules were provided all vessels through the medium of the U.S. Hydrographic Offices.

SERVICES RENDERED OTHER GOVERNMENT DEPARTMENTS

Following the war the naval shore radio system continued to handle radio communications for other Government departments. No charges were made for this service and, in the interest of economy, no accounting was made. It was estimated that this service saved the Government approximately $1 million per annum during the period 1919–25.

These services consisted of securely handling the large volume of traffic concerned with peace negotiations and our Armed Forces remaining in Europe; the handling of traffic concerning rehabilitation of Europe; the utilization of the shore radio stations for transmission to and reception of traffic from Coast Guard and Shipping Board vessels; the collection of hydrographic and meteorological information; the utilization of existing shore radio stations as part of the airways communication system of the newly established postal airmail system; as a means of communication with lighthouses and lightships and with remote forest areas; the provision of broadcast facilities for the governmental agencies; and assistance to scientific missions supported or approved by the U.S. Government.

POSTWAR ORGANIZATION OF THE SHORE SYSTEM

Following the return of the long-distance radio circuits to the commercial companies, there was a revamping of the naval shore radio system. This was more of a reorientation than a reorganization, and was necessitated by the requirements of providing coastal radio stations and point-to-point services in some areas. Increased ranges of equipments developed during the war years also permitted the use of higher powered, longer distance circuits serving the fleet and our insular possessions.

Stations were divided into three categories in accordance with assigned missions, as follows: [3]

High-powered stations, capable of transmitting at least 3,000 miles, located at strategic points in the United States and its possessions to insure communications with the fleet in any part of the world and for intercommunications with similar adjacent ones. They were not normally used for direct communications with ships, but transmitted messages to fleet units by broadcasting, utilizing either the intercept or the no-answer method.[4] These stations were equipped with arc equipments emitting only waves.

Medium-powered stations, capable of transmitting at least 1,000 miles, for the purpose of connecting adjacent naval districts and to provide long-distance ship-shore service. These stations also used the intercept and no-answer broadcast methods and were equipped with medium-powered arc equipment emitting only continuous waves.

Low-powered stations, with transmission ranges of less than 1,000 miles, situated along the coast to provide close-in ship-shore service and communications with the naval district headquarters, the location of the district communications center. These stations were normally provided with low-powered arcs equipped with choppers, or with spark transmitters.

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[3] A list of these stations as of 1921, with improvements and changes through 1925, is contained in app. L.

[4] In the intercept method one shore station transmits to another shore station which, in turn, repeats back to the first station. The ship for which the message is intended receives the message but does receipt for it. In the no-answer method a single shore station transmits a message on schedule which is received, but not receipted for, by the ship to which it is adressed.

All stations were connected with their own district centers either by landline or radio. In many cases the transmitting stations were keyed by landline and the receiving done at the district center via monitor stations and tone channels. Each high-powered station included a medium-powered one and, likewise, each medium-powered station included a low-powered one to insure a completely integrated system.

DEVELOPMENT OF THE USE OF HIGHER FREQUENCIES

Despite the tremendous successes the amateurs and the Naval Research Laboratory were experiencing in the higher frequencies, the Bureau of Engineering was reluctant to accept the use of these frequencies as a solution to its long-distance radio communications problems. Taylor was spending much of his personal time pursuing his research in these frequencies because of the apparent general lack of understanding of the potentialities they offered. Although Hooper strongly advocated the development of the vacuum tube transmitter, his efforts were concentrated toward obtaining equipment of sufficient power to utilize the portion of the radio spectrum then being used. Typical of the attitude of the Bureau in the early twenties was the almost complete lack of interest evidenced when Taylor reported his discovery of echo ranging and his view that this phenomenon possessed enormous potential. Much of the failure to pursue this phase of development has been blamed on economy and insufficient funds but, at the time, considerable sums were being expended in the development of low-powered arc transmitters, higher powered tube transmitters, and toward the improvement of the high-powered arcs. When we contrast the $250 cost of a single high-power, low-frequency tube with the $289 expenditure for a homemade 250-watt high-frequency transmitter and receiver capable of providing reliable communications in excess of 5,000 miles,[5] this argument is hard to understand. It is true that these early high-frequency transmitters lacked frequency stability. Later ones, with the necessary stability, required a piezoelectric crystal for each frequency utilized. But this was not a deterring factor insofar as shore stations were concerned. and not a serious one for shipboard long-distance radio communications since, normally, one day and one night frequency sufficed.

In March 1923 the Government agreed to take steps to abandon the use of the broadcast band except on a noninterference, coordinated basis. This was strenuously opposed by Hooper.

In July 1923 Hooper was ordered to duty as Fleet Radio Officer. He was relieved as Head of the Radio Section by McNeely, a capable officer who had had no previous connection with radio matters and who possessed no firm convictions regarding them. After a study of the situation, he made no radical changes in the Bureau's radio equipment procurement plan, but he did support Taylor's program of high-frequency and research and instigated investigations relative to means of transmitter stabilization. Further, he directed that ships and stations be equipped with high-frequency receivers as rapidly as funds would permit. Radio personnel in ships and at stations were encouraged to construct high-frequency apparatus, and many did so utilizing their own funds and parts salvaged from obsolete equipment. The first among these were the personnel at the stations at Balboa and San Diego and in the U.S.S. *Tennessee, Utah, Wyoming, Canopus,* and *Patoka,* followed rapidly by numerous others.

In early 1924 the dirigible U.S.S. *Shenendoah* was nearing completion and, at Taylor's urging, McNeely obtained authority to fit her with high-frequency radio equipment manufactured at the Naval Research Laboratory. In October of the same

[5] Communication Division Bulletins Nos. 33 and 34 of September and October 1925.

year she made her shakedown cruise across the United States and return. The sight of a naval unit operating in midcontinental areas attracted widespread attention but not more than the remarkable results obtained with her radio equipment. Transmitting on a frequency of 3200 kc. she was able to maintain reliable communications with the Laboratory, which was operating on 5500 kc. for about 7 hours each night of the voyage. While she was moored in San Diego her transmission were heard and copied by the U.S.S. *Canopus*, distant 4,200 miles. On the round trip she was constantly in communication with amateurs throughout the country. This was not a crystal-controlled transmitter and there were problems of frequency stability. Since the transmitter operated only on a frequency of about 3200 kc., daylight range was extremely limited. Little success was obtained in operating with shore radio stations and fleet units on lower frequencies with her normal equipment. This may be attributed to the fact that her radio personnel were more keenly interested in using the high-frequency equipment. The Commander in Chief, U.S. Fleet, was unsympathetic to these achievements and commented upon the necessity of dirigibles, which were to be assigned as fleet units, becoming proficient in communicating with shore and fleet units on standard frequencies rather than being used as airborne laboratories.[6]

It is of interest to note that Capt. Ridley McLean,[7] USN, became Director, Naval Communications, in July 1924. The monthly bulletins of his division make no comments pertaining to the use of high-frequency radio prior to the shakedown flight of the U.S.S. *Shenandoah*. Following this event, these bulletins indicated ever-increasing interest in the use of this portion of the spectrum and that McLean was not only in full sympathy with the program of McNeely but encouraged it. In his bulletin issued on 15 December 1924 McLean commented upon the rapid increase in the use of higher frequencies and correctly prophesied that they would be used extensively by commercial stations.

Upon the completion of the first crystal-controlled transmitter by the Naval Research Laboratory in late 1924, McLean authorized it for use in handling traffic between Washington and Balboa. This one-way circuit proved extremely successful, and the transmissions were copied by practically all units that had constructed high-frequency receivers. Within 1 month, additional one-way night-traffic circuits were established with London, San Diego, San Francisco, and Pearl Harbor.

In early 1925 it was decided to send the U.S. Fleet to Australia and New Zealand during the following summer. This afforded an excellent opportunity to convince the fleet that high-frequency communications were reliable and would prove satisfactory for long-distance ship-to-shore communications. Lt. Frederick Schnell, USNR, Traffic Manager of the American Radio Relay League, was ordered to active duty during the period of the cruise. Through his efforts, satisfactory nighttime communications were maintained between the flagship, U.S.S. *Seattle*, and the Naval Research Laboratory during the entire period of the cruise.[8]

Following the successful demonstration of this portion of the frequency spectrum, the Commander in Chief recommended equipping some of the more important fleet units with high-frequency equipment to provide limited long-distance, ship-shore communications. He further recommended that frequencies higher than 9000 kc. not be utilized. Meanwhile, Taylor and Hulbert of the Laboratory, in conjunction with the Carnegie Institution, confirmed the Kennelly-Heaviside theory. They also gained additional information concerning the diurnal changes in the height of the ioni-

[6] Communications Division Bulletin, 15 Nov. 1924.

[7] McLean was born in and appointed a naval cadet from Tennessee. He graduated from the Naval Academy in 1894. He died on board the U.S.S. *Nevada* as a rear admiral on 12 Nov. 1933.

[8] Supra, Ch. XXXVIII.

spheric layers above the earth. These changes accounted for the fact that the frequencies which were used for communications during darkness were of little value during daylight. It was discovered that still higher frequencies were necessary during daylight. With this knowledge at hand, the Department could not accept the frequency limitation recommended by the Commander in Chief.

A sizable appropriation[9] for modernization of radio equipment was obtained and a program for the design and development of low-powered, high-frequency equipments for point-to-point and ship-shore circuits was initiated. This program required several years to implement. During that period there was a constant increase in the number of high-frequency, point-to-point circuits established, utilizing homemade transmitters and receivers, and in the amount of traffic handled by each of these circuits.

It was well realized by naval radio engineers that all the requirements of naval communications could not be met by the use of high frequencies alone. There was still the problem of skip distance, making it impossible to entirely cover all ocean areas entirely from available shore-station locations. Since attenuation of signals in seawater increases with frequency, satisfactory transmissions to submerged craft in remote ocean areas necessitate the use of very low frequencies emanated at extremely high power. Our growing submarine force required the provision of reliable broadcasts which they could receive in all possible operating areas while at periscope depth. These two requirements necessitated the continued use of high-powered, low-frequency transmitters that could be utilized for broadcasting necessary information and orders in conjunction with similar broadcasts at high frequencies. The arc transmitters would suffice to fill this requirement until the later satisfactory development of high-powered electronic transmitters. This left the Bureau free to develop low-powered tube transmitters covering the full spectrum by now expanded upward to 20,000 kc.

For the first time, wave propagation throughout the entire range of this spectrum was understood, and this afforded the opportunity of charting a course which could be followed for many years. Based upon this, Craven was able to develop a workable naval communications frequency plan in which he took cognizance of commercial point-to-point, mobile, and broadcast requirements, thus eliminating to the greatest possible extent interferences between the various usages. Later, this plan would be adopted internationally and would make it possible for mobile communications to be operated worldwide with a minimum of interference.

[9] Ibid.

PART III

The Electronic Age

CHAPTER XXXIV

Roles and Problems of the Navy During the Electronic Age

PROLOG

The period between World Wars I and II and extending through the latter has often been called the electronic age. During this time improvements in vacuum tubes resulted in the devising of systems for their use which far overshadowed the radio communications for which they were initially developed. Some of these systems, developed under the impetus of "total war," caused an almost complete change in naval and air warfare and to some extent in land warfare. The electronic age may be divided into four periods.

THE BEGINNING OF THE ELECTRONIC AGE

The first of the periods includes the years between the end of World War I and the "radio broadcast boom" in 1922. During this time the Navy was the principal U.S. user of radio. Naval officers in control of radio policy considered that the future of reliable radio communications rested in the use of the narrow band, continuous waves generated by electronic equipments. At this time they were the sole supporters of the development of vacuum tubes and electronic equipment, and considerable sums were expanded in the hope of encouraging manufacturers to carry on the necessary work. The return on these expenditures were relatively meager and the equipments provided were in most part unreliable. The role of the Navy in encouraging the development of modern electronic communication equipment has been related in part II of this work.

THE BROADCAST ERA

The second period commences with the advent of radio broadcasting and continues through the "boom" period of the twenties. It is second in importance only to the World War II period. The radio broadcast industry was born and developed during this period and from this stemmed the rise of the American electronics industry. It also marks the beginning of industrial research in electronics, for heretofore most of the productive radio research had been conducted by or for the Navy. From the naval viewpoint the period marks the final development of an adequate and reliable radio communication system. Toward the end of this period naval radio plants were fitted with the best equipment in the world. The early part of these developments is covered in detail in part II. The remainder will be related in the following chapters.

The development of the radio broadcast industry in this country was hampered to a large extent by controversy between the radio and telephone groups over the question as to which possessed vested interest in broadcasting. This struggle continued for several years and ended only when the American Telephone & Telegraph Co. quit the broadcasting field in June 1926.

Some fundamental and therefore vital areas of growth in the electronics industry were retarded by monopolies of the Radio Corp. of America in the sales of certain radio components and in radio communications. As the sole radio sales agency of its two corporate parents the General Electric and Westinghouse Cos. and as a holder of most of the basic radio patents, it early endeavored to eliminate all other radio manufacturers regardless of previous patent rights. These actions stimulated Congress, in 1923, to direct the Federal Trade Commission to investigate the radio industry in the United States. Although the commission did not return an unfavorable report against the Radio Corp., it did create sufficient publicity for the latter to amend its practices and to license reliable firms at fairly high royalties. As the years passed these royalties were lowered to a reasonable level. However, the actions of the Radio Corp. and the General Electric and Westinghouse Cos. were sufficient to cause the Government to consider the possibility of the existence of a trust coalition. In May 1930 the Department of Justice instituted proceedings against the Radio Corp., its affiliated companies, and its corporate parents. This was finally settled by a consent decree in November 1932 wherein the General Electric and Westinghouse Cos. agreed to divest themselves of their interests in the Radio Corp.

The advent of broadcasting posed a problem for the Navy. The number of broadcast stations mushroomed, especially in the large centers of population near our seacoast. These stations used the same portion of the frequency spectrum as had long been used by the Navy and there was no means to prevent them from so doing. Interference increased as the number of stations increased. The numbers of broadcast receivers purchased during these early years attests the popularity of this new medium of entertainment. The Navy's use of frequencies near those of broadcast stations brought forth floods of protests. Previous funds, from an appropriation which had been drastically reduced as a result of the Washington Conference on the Limitation of Armaments, were utilized in an endeavor to reduce the interferences caused by the arc and spark transmitters. This, in turn, resulted in a reduction of funds available for the development of electronic radio equipment. Heretofore the Navy had supported the larger radio manufacturers in research for better tubes and for the development of satisfactory electronic transmitters. Lacking sufficient funds, this support had to be withdrawn at a time when communications were unsatisfactory for the handling of a unified fleet and before commercial interests were successful in developing satisfactory equipment. To alleviate the unsatisfactory condition of naval communications, naval research personnel resorted to modifying spark transmitters by replacing the spark gaps with vacuum tube oscillating units and thus developed an alternating current vacuum tube transmitter. These proved to be reliable stopgap equipments for intermediate and long-distance purposes. For intrafleet work they were forced to develop a keying unit for the low-powered short-range voice tranceiver developed for use in submarine chasers during World War I.

The increased usages of frequencies below 1,500 kc. caused the Navy to institute a study of the behavior of higher frequencies. In cooperation with the amateurs much information was gained. In 1925, during a voyage of the fleet to Australia and New Zealand, higher frequencies were successfully used for communication between the fleet and Washington. Following this a new frequency plan was evolved, and from this a long-range modernization plan was drawn up. In the meantime, under public pressure, the Government had agreed to use the broadcast band only on a noninterference basis as soon as practicable.

While engaged in the study of the higher frequencies, personnel of the Naval Research Laboratory first noted that radio waves were reflected by objects and could be utilized for object detection. The recommendation that this be developed into a detection and locating system was made at that time, but the combination of limited funds, the need of improving radio communications, and the inherent conservatism of naval officers concerned with radio resulted in a failure to develop radar at that time.

In cooperation with the Carnegie Institution, in a study of the ionosphere, personnel of the Navy's Laboratory, in 1925, developed a pulse transmitter which was used for measuring ionospheric heights.

In furtherance of the Navy's radio modernization plan the Laboratory's personnel designed and developed high-frequency transmitters and receivers for naval usage. In seeking a means to eliminate the instability of the transmitters, they designed, developed, and constructed the first crystal-controlled high-frequency transmitter.

By the time the depression hit the country, sufficient modern transmitters and receivers were under contract to complete the revised 1926 modernization plan. In 1930 the installation of this equipment was completed; afloat and ashore, the Navy possessed the best and most reliable radio communication system in the world. This was to prove unfortunate for it resulted in reduced naval research in this field for the following decade.

By 1930 the spark and arc transmitters had practically disappeared. Installation of new spark equipment was outlawed. Radio, which had originally been developed as a means of communications had become primarily a mode of entertainment and its former use was relegated to a secondary position, especially in the minds of the public. This had resulted in the necessity for tighter governmental control and had resulted in the temporary establishment of the Federal Radio Commission which was first headed by a retired naval officer. Later this Commission was made permanent and its title changed to the Federal Communication Commission.

With the firm establishment of this regulatory board as the guardian and supervisor of commercial radio usage, the position of the Navy as Government spokesman for the industry drew to a close after two decades of endeavor to maintain the medium under necessary restrictions.

In the field of sonar, research was continued at the Naval Research Laboratory, and steady improvement was obtained, thus increasing knowledge of oceanography.

Research in flying missiles and radio-controlled aircraft was continued for the first half of this period but was finally halted by the slow rate of progress, the high cost of the work, and by reduced appropriations. The development of radio-controlled torpedoes, commenced during World War I, was completed in 1925.

RADIO DURING THE DEPRESSION YEARS

The third period, which began in 1930 and ended with Hitler's invasion of Poland, was the result of the economic condition which settled over the world late in 1929. It is characterized by a limitation in research and development by both the military and commercial interests. Sales of commercial equipments fell off rapidly as unemployment rose and this forced many of the smaller manufacturers to close their businesses. The larger and more financially stable ones began the manufacture and sale of smaller compact receivers which sold at a much lower price. The two broadcast networks managed to continue operations at greatly reduced revenues. This was possible only because radio suddenly, because of its relatively low cost, became the country's prime means of entertainment and, since it provided the cheapest mode of advertising, permitted the continuance of broadcasting. At the beginning of the depression television was being developed, and this work was continued by the larger companies but on a much reduced scale.

The Navy, with its appropriations cut to the core, was forced to drastically curtail its research program and at one time considered disestablishment of the Naval Research Laboratory. Early work on the decade frequency synthesizer, commenced by Dr. R. M. Page of the Laboratory in 1932, was instrumental in averting such a calamity. Some few improvements were made in radio equipment by service personnel, but these were limited in nature. The Dow electron-coupled circuit was devised to eliminate the necessity for crystal-controlled high-frequency transmitters, and better frequency standards were devised. Work was begun on a tactical radio transceiver using a frequency of about 60 mc. Research and development of electronic security equipment was begun but on a very limited scale. The Laboratory was able to continue its improvements on sonar.

On 14 March 1934, when the economic situation had stabilized, work was commenced on the development of pulse radar at the Laboratory, and surprising progress was made by a small group of personnel. Later, congressional and military interest in the capabilities of the system was aroused, and Congress made direct appropriations in support of its development. Likewise, interest in the development of radio-controlled aircraft for antiaircraft target purposes was revived because of our lagging air defense.

Throughout the period unrest was growing and war clouds began to appear on the horizon. The economic situation in the United States had commenced to stabilize and improve, but Hitler's political victories in Germany and Japanese actions in China forced us to step up our defenses and brought to an end the limitation of research in weapons systems.

WORLD WAR II DEVELOPMENT

The fourth period, extending beyond the successful conclusion of World War II, was a period in which far greater progress was made in the development of weapons systems than had ever been made during the lifetime of any single generation. Especially was this true in the development of systems utilizing electronic principles. Such progress could have been achieved only by a total alliance between: The users, in this case the military, which stated in broad terms its equipments requirements; the researchers, organized for total war, who developed these equipments and constructed "bread board" models; the designer-engineers who converted the "bread board" models into usable and manufacturable equipments; and a mobilized industry, capable of mass production of the necessary devices and systems.

Fleet Adm. E. J. King, USN, who was concurrently Chief of Naval Operations and Commander in Chief, U.S. Fleet, in his third report to the Secretary of the Navy, dated 8 December 1945 stated:

> Perhaps the greatest technological advances of the entire war have been made in the field of electronics, both within the naval laboratories and in collaboration with the Office of Scientific Research and Development. Pre-existing radar sets were developed and new methods created for ship and airborne search, fire control and for accurate long-range navigation. Identification and recognition equipment were developed for use in conjunction with radar systems. New and highly efficient short-range radio telephones were used for tactical communication. In the successful anti-submarine campaign in the Atlantic, small radio-sono-buoys were used; these when dropped from aircraft, listened for the noise made by a submarine and automatically relayed the information to the searching plane. Underwater echo-ranging gear and listening equipment have been improved in quality and extended in function since the outbreak of the war. Countermeasures have been developed for jamming enemy radar and communication systems, disrupting the control systems for his guided missiles, and counteracting his measures to jam our own equipment.

This glowing report of achievements in the electronics field fails to include the development of the proximity fuse, which next to radar and sonar was the greatest contribution to electronics made during the period. Additionally, considerable effort was expended upon the development of missiles and, although they were not used operationally to any large extent, had the war been extended they would have been developed into an important weapon.

In commenting on the indispensable

assistance and cooperation of science and industry Fleet Admiral King in the same report stated:

> . . . Without this assistance, many of the weapons which have come into being as the result of intensive wartime research and development otherwise never would have been completed and introduced into the fleet.
>
> It had often been predicted that in a national emergency the totalitarian countries would have a great advantage over the democracies because of their ability to regiment scientific facilities and manpower at will. The results achieved by Germany, Italy and Japan do not bear out this contention. Studies made since the close of the war indicate that in none of these countries was the scientific effort as effectively handled as in the United States. The rapid, effective and original results obtained in bringing science into our effort are proof of the responsiveness of our form of government to meeting emergencies, the technical competence of American scientists, and the productive genius of American industry.

There is much that can be said in amplification of this last paragraph. Leadership in research within the Axis Powers was vested in Germany which had, long before World War I, emerged as one of the leading scientific nations. Despite her years of experience in this field, she failed to mobilize her scientific talent in order to devise new weapons and techniques and improve old ones. Instead, the German policy was to establish swift standardization in an effort to obtain maximum production. Allied policy, conversely, demanded better and better weapons, and in the end this resulted in their scientific superiority over the Axis countries in the field of electronics.

The development and application of electronics to warfare had scarcely commenced when we entered the war. Radio communications were still mostly in frequencies below 30 mc. Sonar was fairly well developed insofar as transmitting and receiving equipments were concerned but required much ancillary apparatus to make its use more effective. Radar equipments were still in the experimental stage and few had been installed. The development of this means of detection and location for numerous military purposes is one of the wonders of the age. In addition to these, many other systems were developed during the war, each of which required many advances in design and construction of vacuum tubes, controls, antennas, and other components. Typical of these new developments are the proximity fuse, loran, electronic identification systems, beacons, ground-controlled approach systems for aircraft, automatic bearing indicator direction finders, countermeasures for radio, radar, and sonar, the development of bathythermographs for tactical usage, improved meteorological apparatus, cryptographic and cryptoanalytical devices, the development of communication equipments to carry greater volumes of traffic per kilocycle of band width, and the development of equipment for a greatly expanded communications spectrum which first included the very-high-frequency regions and then expanded into the ultra-high-frequency portion of the spectrum. The vital or important roles of naval research personnel in the development of these systems or devices is related in succeeding chapters. The importance of electronics in modern warfare is best understood when it is realized that it caused revolutionary changes in designs of combatant vessels and aircraft. The magnitude of the development is best described by dollar figures. In 1940 the Bureau of Ships expended $6 million in developing, equipping, installing, and maintaining electronics equipment in ships and at shore stations. One billion dollars was expended for the same purposes in 1945.

The development of electronic warfare equipment was accompanied by other problems of stupendous magnitude. Personnel had to be trained to design these equipments, engineer them for production, install, maintain and, operate them, afloat, in the air, and ashore. The enormous ship and aircraft building programs intensified these problems. Another problem of serious proportions was the proper use of manufacturing facilities and the assurance that Government activities would not be competing for services. The distribution of equipment to the various stock piles to ensure its availability in the various theaters and its proper issue on the most urgent requirements basis from these stockpiles was another enormous undertaking. These problems resulted in a continued expansion of the headquarters facilities responsible for the program. When the Bureau of Engineering and the Bureau of Construction and Repair were consolidated, in June 1940, into a single Bureau of Ships, the Radio and Sound Division lost its status as a division and became the Radio and Sound Branch of the Design Division. The growth of the electronics program in 1940 and 1941 placed the organization, composed of 39 civilian and military personnel, under great strain. This resulted in the only fundamental reorganization of electronics personnel in the Bureau, when, in October 1942, the Radio and Sound Division of the Bureau of Ships was established. At the war's end it had expanded to a total of 1,205 personnel.

From the standpoint of radio communications, many problems arose throughout the war which were either solved or minimized by the actions taken. Here again, as in World War I, the communications reserve personnel rendered invaluable service. The ever-increasing numbers of ships, aircraft, tanks and other mobile weapons called for an ever-increasing number of radio circuits. For short-range requirements channels were set up in the very-high- and later in the ultra-high-frequency portion of the spectrum to provide fairly secure tactical communications. In the high-frequency portions, multiplexing and frequency shifting were resorted to in an endeavor to increase the intelligence transmitted per kilocycle. Circuits were speeded up by the adoption of teletypewriter transmission on point-to-point and on some broadcast circuits. These had the advantage of releasing badly needed telegraphic operators to ships and also reduced the numbers required for training.

The Navy's most serious radio communication problems were in the Pacific theater of operations. In that area enormous radio stations had to be constructed, equipped, and manned to handle a volume of traffic which exceeded several millions of words per day and often exceeded the capacity of all available circuits. This problem was aggravated by the different views concerning message precedence held by the two services and inability to prevent the assignment of unnecessarily high precedences by many originators.

EPILOG

The Navy's requirements for advance electronics systems stimulated invention, improved design, and set the highest possible standards for the industry. It is a giant step from the spark-gap transmitter of a half century ago to the transistorized multiplex of today which can simultaneously transmit 100 words a minute on each of 4 channels. The intricate electronic complexes which look into the sky, under the sea, and direct our guns, missiles, and aircraft, are a far cry from the eyes of a sailor lookout. Yet we merely stand on the threshhold of a new and exciting science. If the past is prologue to the future, and if this history has a meaningful story to tell, you may be certain that for the future defense of this great land, the U.S. Navy will continue to lead and show the way into the vast unexplored realm of electronics.

CHAPTER XXXV

Post World War I Radio Modernization

PROLOG

With the discovery that the three-element vacuum tube could be made to oscillate, radio engineers were provided with a device which could perform all the necessary electronic functions. For almost three decades following discoveries of all its characteristics, its use was almost completely limited to communications. However, following the advent of radar, the proxmity fuze, and other applications with their enormous military propensities and public appeal, communication equipment ceased being of sole importance in the electronic field. Notwithstanding its having been supplanted as the most important electronic development of the age, communication remains the nerve center of all war operations. Without adequate means of conveying enormous volumes of intelligence and commands, operations would be almost paralyzed.

Between 1925 and the outbreak of World War II development of communication equipment had been primarily confined to the spectrum between 15 kc. and 30 mc. Between 1925 and 1929, with the radio boom in full swing, the Navy was almost entirely dependent upon its own research facilities for the development of radio equipment suited to its needs. The radio industry as a whole was far too occupied providing millions of receivers for American homes and in the development of improvements which might increase sales in this highly competitive market. Apparatus designed by Naval Research Laboratory personnel was manufactured for the Navy by the Radio Corp. of America, the Westinghouse Electric & Manufacturing Co., the Western Electric Co., the National Electric Supply Co., and other smaller companies. Practically no research or development of Navy equipment was performed by any of these companies during this period.

With the limited funds available for research and development of communication equipment, for example, $25,000 in 1939, only a few of the technical staff of the Radio and Sound Division were able to concentrate on the development of new equipments. Other personnel of that section concentrated on projects which would produce modifications to existing equipments to meet changes required by the fleet.[1]

As a result of this, when the United States was thrust into World War II, the Navy's need for radio equipment was so dire that it was necessary to reclaim receivers used during World War I and to convert them to the use of tubes and alternating current. Stopgap equipments were made available by modifying commercial designs to make them adaptable to ship installations. Once the immediate needs were filled, this proved more of a blessing than might be supposed. With no war reserve equipment available, new and vastly superior equipment was developed to meet the requirements of our rapidly growing fleet. New techniques in handling large volumes of traffic were developed, and higher frequencies were utilized. New designs, dictated by operational requirements, revolutionized the

[1] "An Administrative History of the Bureau of Ships During World War II" (First draft narrative prepared by the Historical Section, Bureau of Ships), vol. IV, pp. 268–269.

standard functions of communication equipments. Advancements in electronic techniques influenced modification of the existing systems and further permitted the development of new devices having wide and varied applications.[2]

FLEET COMMUNICATIONS CONDITIONS FOLLOWING WORLD WAR I

Following the reorganization of our naval forces in 1923 and the completion of Fleet problem 1,[3] the Commander in Chief of the newly organized U.S. Fleet submitted a comprehensive statement of the communication requirements of his command, based on its operation in modern naval warfare with its complex cruising and battle dis-

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[2] Ibid., pp. 270–271.

[3] The following excerpt from a letter of Rear Adm. Robert E. Melling, USN (retired), is quoted to provide insight of the existent communication conditions.

"In Fleet Problem Number One, held in February 1923 the Black Fleet, under Admiral E. W. Eberle, had the mission of destroying the Panama Canal. The Blue Fleet, under Admiral John D. McDonald, had the job of preventing it from doing so. The Commander-in-Chief, Admiral H. P. Jones, did not like the idea of "constructive" forces, but as the U.S. Navy had no aircraft carriers nor bombing planes, the Black Fleet was allowed to use two battleships to represent carriers. The *New York* and *Oklahoma* were the "carriers," each with 15 bombing planes, 90 knots, 9 hour radius. This action all took place on the Pacific side. Vice Admiral McDonald said, in his Estimate of the Situation, "An attack by bombing planes on the eastern approaches to the Canal has not been considered, as such a plan would be entirely academic . . . Such an attack is impossible with bombing planes as developed at the present time. The mountain ranges necessitate high altitudes." He rightly assumed that the Black Fleet would enter some harbor in Central America from which to launch the air attack on the Canal, as bombing planes could only take off from smooth water (or an airfield). The Black Fleet entered Culebra Bay and the problem ended. It lasted only four days, but it should be remembered that in 1923 the Navy had been practically without funds since the end of World War I, the ships were in poor condition and the crews were skeleton in more ways than one. Engineering casualties were numerous. Leaky condensers in many destroyers caused salted boilers. On the trip from San Diego to Panama three destroyers ran out of fuel and a collision put one destroyer out of the problem. Steering casualties in the battleships kept everyone jittery. The radio equipment consisted primarily of spark transmitters. The battleship flagships had low frequency arcs, which occasionally set fire to the rigging. The destroyers, in addition to a spark main transmitter, had a bulkhead mounted radio telephone transceiver of 5 watts power. As the destroyer captains did not like the radiotelephone, they had been converted to keyed CW, which also permitted written copies of the messages handled. Competition for promotion was brutal in those days, and each skipper in endeavoring to keep his nose clean demanded everything in writing.

"The Black Fleet maintained radio silence, relying on visual signals and submarine oscillators for their necessary tactical signals. Commander Black Fleet sent two R-boats under the command of Bert Rogers to the vicinity of Cape Mala to act as radio decoys. They were given a number of call signs, shifted to various wave lengths, varied their power, and kept the air full of dummy code messages all through the problem. Unfortunately, the Blue Fleet failed to hear any of their transmissions! The visual communications in the Black Fleet were very poor. Some of the destroyers in the outer screen reported getting change of course signals several hours after they had been executed. They weren't left too far behind if on the wrong side, because fleet speed was eight knots. The submarines were deployed way outside the outer destroyer screen, and were not heard from during the problem. One morning the *Oklahoma* (constructive carrier) was ordered to catapult her airplanes for reconnaissance, but the Captain thought the wind was too strong and delayed launching until afternoon. The effort was all in vain, as no reports were received from the plane—the radioman didn't know how to work the radio.

"The Blue Fleet used radio excessively, although Commander Blue Fleet had prescribed minimum use. Pandemonium reigned, although this was not primarily the fault of the communicators. Many false contact reports were originated. The Blue Fleet destroyers making contact with the constructive carriers reported them as battleships, which they actually were. The contact reports took two hours to reach the Blue Commander. The Blue air patrol, consisting of F5L planes with their tenders *Sandpiper* and *Teal*, intercepted the contact and information of enemy reports, but couldn't decode them as they didn't have the books. However, the flagship *Wright* decoded the reports and passed along the plain language translations.

"After radio silence was broken by the Black Fleet, near the end of the problem, they found that in some cases both Fleets were using the same frequency. The Black Fleet used these:

positions.[4] His recommendations were approved by the Secretary of the Navy.

Following World War I the Bureau of Engineering, with Hooper in charge of the Radio Desk, had placed great emphasis and expended considerable funds in an unsuccessful attempt to develop satisfactory vacuum tube transmitters and radio equipment which would afford reliable communications between aircraft and surface vessels. Some thought had been given the problem of multicircuit operation aboard ship, but the envisioned requirements fell far short of those established by the Commander in Chief. His report contained the first complete statement of radio requirements which had been received by the Bureau prior to the beginning of World War I.[5] Immediate action was essential to provide sufficient reliable secure channels of radio communication to permit full efficient operation of a large group of vessels in a restricted area and to maintain communications with scouts hundreds of miles distant.

INTERIM MEASURES TO IMPROVE FLEET COMMUNICATIONS

The Bureau immediately commenced formulation of a plan of modernization and instituted stopgap measures to alleviate the unsatisfactory conditions pending final development of a modernization plan. One of these stopgap measures included the modifying of many of the old spark transmitters by replacing the spark with an alternating current vacuum tube circuit in accordance with a scheme developed by Mr. A. C. Speaker, a naval radio engineer. Other measures included the substitution of the spark in low-powered sets by motor-buzzer sets and the modification of the CW 936 transceivers to provide for low-powered tactical communications, the improvement of the arc transmitters to eliminate mush and harmonics, and the installation of acceptor-rejector systems to eliminate interference between different radio communication channels and to make possible dual reception on a single antenna.[6] These modifications improved the situation, but they were complicated and unreliable and could be considered only as interim measures. Hooper was ordered to duty as Fleet Radio Officer in an endeavor to bolster radio communications within the Fleet. He reported for this duty in July 1923 after having been relieved of his duty in the Bureau by Capt. R. W. McNeely, USN.

DEVELOPMENT OF SATISFACTORY LOW-POWERED LOW-FREQUENCY VACUUM TUBE TRANSMITTERS

Previous to this time, the Naval Research Laboratory had developed the Model TO tube transmitter of 100-watt power, covering the frequency band 500–1500 kc. Concurrently, the Western Electric Co. had been provided a contract to develop Model TP of 150-watt power covering the frequency band 75–600 kc., and the General Electric Co. had been provided a contract for the development of the Model TU of 2-kw. power operating in the frequency range of 195–565 kc. All of these, controlled by rigid Navy specifications, were satisfactorily developed and contracts for their manufacture were negotiated as follows:

	KC
Protective Screen (Submarines)	444.4
Outguards	375
Pickets	277.8
Bombing Detachment	250
Supports	209.1
CinC Long Wave	76

"Among the complaints—the submarines had only one radioman and most commanding officers thought they should have more. Commander Blue destroyers said there were too many radio messages, his flagship sent, received or intercepted 95 messages during the problem."

[4] Commander-in-Chief, U.S. Fleet, Annual Radio, Sound and Pigeon Report, 3 Apr. 1923.

[5] Letter, dated 6 Mar. 1926, Bureau of Engineering to the Chief of Naval Operations and Commanders in Chief United States and Asiatic Fleets.

[6] Supra, ch. XXXII.

No.	Model	Contract year	Contractor
21	TO	1923	Westinghouse Electric & Manufacturing Co.
1	TO	1923	Washington Navy Yard.
23	TP	1923–25	Western Electric Co.
5	TU–1	1923	General Electric Co.
8	TU–2	1923	Western Electric Co.

The Model TO were purchased for installation in battleships for tactical communications and the Model TP for fleet and force flagships and battleships for general communications.

In addition, the Western Electric Co. developed, under contract, a loading inductance for the Model TL transmitter of 6-kw. power which permitted its use at the frequency of 75 kc. Two of these were purchased in 1923 for installations on the flagships of the Fleet and Battle force commanders.[7] By early 1924 a few of these equipments had been delivered and installed in the more important flagships.

IMPROVEMENT OF BROADCASTS TO THE FLEETS

Prior to and during 1924 improved transmitters for shore stations were placed under contract as shown in table below.

These transmitters were used for broadcast schedules with the fleets.[8]

INITIAL ENDEAVORS IN DEVELOPING THE RADIO MODERNIZATION PLAN

McNeely proceeded with the development of the radio modernization plan. Immediately, things began to occur which necessitated changes to the requirements submitted by the Fleet. The Interdepartmental Radio Advisory Committee agreed to vacate the 500–1500-kc. band, used for fleet tactical communications, except on a noninterference basis. The Navy was forced into reluctant agreement. Hooper did not concur in this. This decision forced the Navy to commence the design of models TV, TW, and TX transmitters covering the frequency band 2–3 mc. A few months later, in February 1924, the Commander in Chief's comments upon receivers combined with the necessity of providing a receiver covering the 2–3-mc band resulted in the U.S. Naval Research Laboratory being directed to develop models RE (10–100 nc.) and RF (75–1000 kc.) series of receivers. At this time, Taylor, at the U.S. Naval Research Laboratory, was obtaining spectacular results in the use of higher frequencies at low power for long-distance communications.[9]

TENTATIVE MODERNIZATION PLANS

On 27 March 1924 the Bureau of Engineering submitted the Commander in Chief, U.S. Fleet, a tentative technical solution of his radio requirements. Concurrently, it sought and obtained an appropriation of \$1½ million for fiscal year 1925 to carry out this proposed plan. Unfortunately, this appropriation was obtained before full realization of the magnitude of the modernization program was fully appreciated. Some of it was utilized in the purchase of transmitters covering the 2–3-mc. band, for

[7] Bureau of Engineering Radio and Sound Bulletin, July–December 1931, pp. 96–101.

[8] Ibid., p. 99.

[9] Supra, ch. XXXII.

Station	Contractor	Year	Power	Frequency range
Arlington	Washington Navy Yard	1923	10	64–118
Arlington	Washington Navy Yard	1924	20	86–112
Arlington	Washington Navy Yard	1923	3	100–500
San Diego	General Electric Co.	1924	80	25–35
Cavite	Navy Yard, Mare Island	1924	6	56–355
Hawaii	Navy Yard, Mare Island	1924	6	56–355

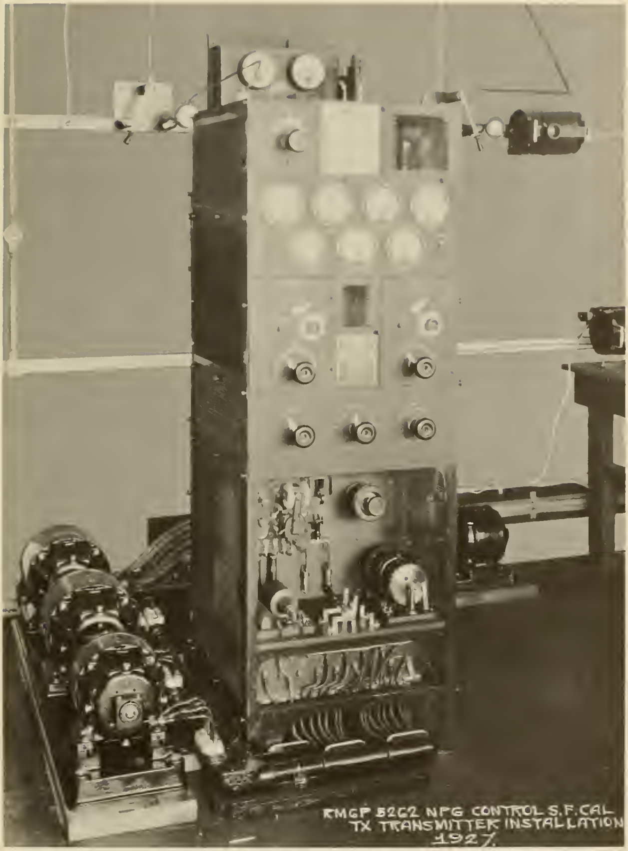
RMGP 5262 NPG CONTROL S.F. CAL
TX TRANSMITTER INSTALLATION
1927.

FIGURE 35–1.

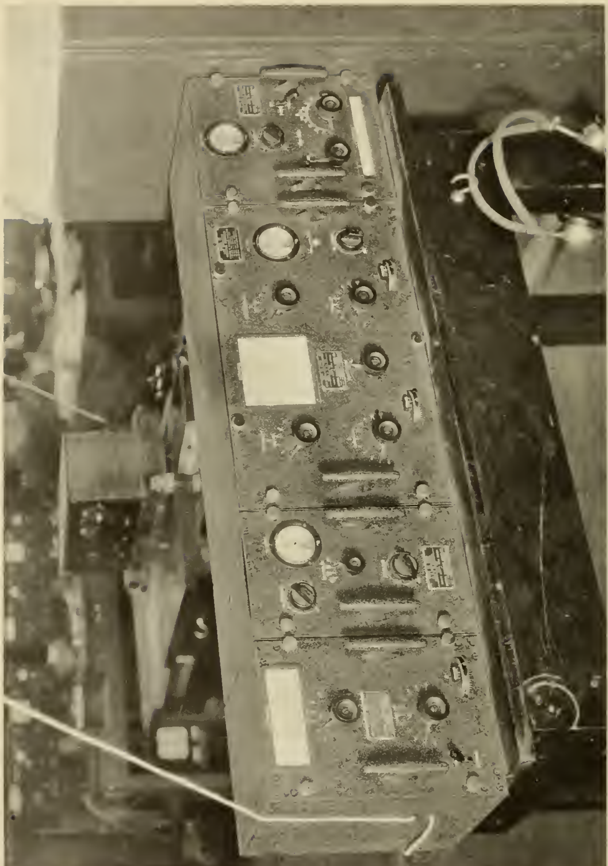

FIGURE 35–2. Model RE low frequency receiving equipment.

aircraft transceivers, and newly developed low- and medium-frequency receivers. The amount was far in excess of that which could be spent. Although the research activities of the General Electric, Western Electric, and Westinghouse Electric & Manufacturing Cos. were engaged in developing tube transmitters and the Naval Research Laboratory was developing a high-frequency receiver, these were not yet ready for manufacture. In fact, the use of high frequencies had not yet entered the plan.[10]

It had been planned to utilize some of the fiscal 1925 funds for duplexing the radio installations in many of the major ships. Failure to coordinate this with the Bureau of Construction and Repair resulted in that Bureau not requesting the necessary funds for ships' alterations. Additionally, attempts to obtain allocations of space to separate receiving and transmitting equipment met with failure. Only a small portion of the appropriated funds was utilized for radio. Foreseeing this would occur, Hooper expressed his opinion of the situation in a critical and sharply worded letter to McNeely.[11]

EFFECT OF HIGH-FREQUENCY COMMUNICATIONS ON THE MODERNIZATION PLAN

By the end of 1924, Taylor's success in the use of high frequencies had convinced McNeely and McLean, who was then the Director of Naval Communications, of the feasibility of utilizing this portion of the radio spectrum for intrafleet, ship-shore, and point-to-point long-distance radio communications.

In early 1925, a naval communications frequency plan utilizing frequencies from 15 kc. to 19 mc. had been drawn up, approved, and the necessary allocations requested and obtained. Then, on 25 February 1926, the Interdepartmental Radio Advisory Committee approved the recommendation of its Subcommittee on Technical Problems. This recommendation stated:

> The frequency allocation proposed by the Navy for its use is a scientific and systematic allocation. The plan permits an economical utilization of the ether.
>
> For peace use it gives consideration to the requirements of Government and non-Government activities and is in accord with the band allocation approved by the Fourth National Radio Conference.[12]

During the summer and fall of 1925, advantage was taken of the U.S. Fleet cruise to Australia and New Zealand to test the use of high frequencies for ship-shore communications. These tests, conducted under the supervision of Taylor, demonstrated the superiority of low-powered, high-frequency transmision for long distances. On 5 November 1925, final decision to include high-frequency equipments in the radio modernization plan was made.[13]

PROBLEMS OF REVISION OF THE RADIO MODERNIZATION PLAN

This decision necessitated an almost complete revision of the Bureau's plan submitted in March 1924 and which had finally been approved by the Commander in Chief, with some reservations, in July 1925.[14] The problem confronting the Bureau was analogous, yet more complicated, to that which existed in 1912, when it was discovered that 30-kw. arc transmitters gave results comparable to those of 100-kw. spark transmitters. Similarly, the recent development of 20-kw. low-frequency vacuum tube transmitters with a performance equal to the 100-kw. arc transmitter, gave indication that the latter type, in which the Navy had invested approximately $1 million, would soon be

[10] Supra, ch. XXXII.

[11] Letter, dated 24 June 1924, from Hooper to McNeely.

[12] Letter, dated 4 Mar. 1926, from Chief of the Bureau of Engineering to the Chief of Naval Operations.

[13] Bureau of Engineering Monthly Radio and Sound Report, December 1925, January–February 1926, pp. 1–16.

[14] Letter, S67 (5), dated 10 July 1925, Commander in Chief, U.S. Fleet, to the Chief of the Bureau of Engineering with Chief of Naval Operations endorsement, dated 11 Aug. 1925.

obsolescent. If high-frequency vacuum tube transmitters requiring much less power could be utilized for many of the naval communication requirements, much money and weight and space could be saved.

The problem was further complicated by a general lack of understanding of the nature of the shorter waves, although some progress had been made by scientists and amateurs in studies of their characteristics. It was thoroughly realized by many of these that in using the higher frequencies the skywaves were utilized for long-distance communications and the groundwaves for short distances. It was also known that there exists an area beyond which the groundwave carries, yet short of the distance where the first reflection of the skywaves returns to earth. This skip-distance area varies with the frequency used and with atmospheric conditions which cause variations in the height of the ionospheric levels. The lack of understanding of the fleet radio personnel is evidenced by the Commander in Chief, US Fleet, Adm. R. E. Coontz, USN, in a letter of 16 September 1925 wherein the recommendation was made that no frequencies higher than 9000 kc. be utilized.

Spark transmitters were to be eliminated from future consideration. The Bureau had to determine: Whether low-powered, high-frequency transmitters would render service ashore and afloat, equal or superior to that rendered by the high-powered, low-frequency, vacuum tube and arc transmitters then installed; whether high powered, low-frequency, vacuum tube transmitters should be used to replace the reliable, rugged arcs which were still capable of rendering service to the fleet, especially with the great improvement in their emanation characteristics brought about by recent current transformer and inductive coupling modifications; and whether, presuming that the vacuum tube transmitter was to become standard, the arcs be still further refined to render them capable of meeting the requirements of standby transmitters.

The large number of communication channels in operation necessitated the continued use of low and medium frequencies for other than long-distance traffic, but these transmitters required little power since they were for intrafleet purposes. However, scouting vessels, fleet submarines, and aircraft required longer range communications which could be afforded only by the use of low-powered high-frequency or high-powered low-frequency transmitters. Decision was reached that the Bureau must proceed immediately with the development of high-frequency equipment to avoid unnecessary future expenditures and to improve the efficiency of the Naval Communications System.[15] The Naval Research Laboratory was directed to develop the necessary transmitters and receivers.

It is of interest to note that, at this time, the Bureau shipped 15 of the old reliable CW 936 transceivers to the Asiatic Fleet with instructions and kits for modifying them for use on 3750 and 7500 kc.[16] In comparison with a practice soon to be adopted, which prohibited modifications to radio equipments except by specific direction, radio personnel, afloat and ashore, were encouraged to construct high-frequency equipments for naval usage.[17]

The problem of providing duplex radio installations in major ship types was resolved by the approved report of a Ship Control Board, convened in 1924, which specified locations for radio installations in all types of naval vessels.[18]

1926 MODERNIZATION PLAN

On 8 March 1926, the Chief of the Bureau of Engineering advised the Chief of Naval Operations and the Commanders in Chief of the United States and Asiatic Fleets of the details of the Bureau's radio modernization program.

[15] Bureau of Engineering, Monthly Radio and Sound Report, December 1925, January–February 1926, pp. 32–34.

[16] Ibid., p. 11.

[17] Ibid., p. 26–27.

[18] Ibid., March–April 1926, p. 10.

This plan was based upon the following factors:

The use of a selective non-interfering system permitting the simultaneous use of the required number of communication channels.

The character of individual ship installations to be such as to permit efficient handling of battle and strategic communications.

The equipment installed to be such as to permit the required expansion necessitated by aircraft, long-range firing, and increase in size of the fleet with its consequent decentralization of command.

The location of radio spaces and the installation of interior communications for radio to be as prescribed by the report of the Ship Control Board, 1924.

The provision of accurate means of equipment calibration and frequency measurements in order to maintain the reliability of the selective system.

The provision of rugged, reliable, operationally simple equipment which will maintain, within a small percentage, stability under the adverse conditions encountered on board ships.

The standardization of installations, making for increased flexibility, economical purchasing, and maximum intercommunications between the various types of vessels.

The utilization of high frequencies wherever possible in order to save weight and space and for economy.

A scientific fleet radio frequency plan which reduces interference to a minimum and requires a minimum of channel shifting with changes in cruising and battle dispositions.

That the plan will be carried out in annual stages consistent with congressional appropriations and the ability of manufacturers.

A study of the type installations shows that the plan included providing high-frequency equipments to all fleet and force flagships, battleships, first-line aircraft carriers, heavy cruisers, first-line light cruisers, first-line fleet submarines, and large patrol vessels.

	Heterodyne frequency meter	Receivers RE	RF	RG	Transmitters TU	TV, TW, TX [1]	XA [2]	XC
Battleships	18	18	18 (3)	18 (2)		18	2	
Cruisers	16	1 (2)	3 (3)	3	10	11	3	
		16	10 (2)	10 (2)				
Destroyers	103	[3] 103	103	38	[4 5] 50	95		
Minelayers	8	8	6					
			2 (2)					
Aircraft carriers	3	3	1 (2)	2 (6)	2	2 (2)		
			2 (6)					
Auxiliaries	18	91	17 (3)	18	[6] 18	8	2	
			37	1 (2)				
Fleet submarines	4	4	4	4	[6] 3	4		
Gunboats	6	6	6	6			1	8
Total [5]	176	251	311	139	83	140	8	8

NOTE.—Number in parentheses indicates number of sets if more than 1.

[1] Basically, these 3 transmitters were identical and should have been designated TV, TV–1, and TV–2.

[2] All ships in this column are fleet and force flagships.

[3] This was later changed to provide 1 for each destroyer squadron and division leader.

[4] 3 previously equipped.

[5] 50 additional TU transmitters to be purchased during fiscal year to complete installations in 3 destroyer squadrons.

[6] 1 previously equipped.

IMPLEMENTATION OF THE 1926 MODERNIZATION PROGRAM

Having promulgated the plan, the Bureau lost no time in beginning its implementation. All previous improvement instructions were canceled, and additional equipment installations listed in the following table were directed:

Frequency Bands

Receivers:	
RE	10–100 kc.
RF	75–1,000 kc.
RG	1,000–20,000 kc.
Transmitters:	
TU	195–565 kc.
TV–TW–TX	2–3 mc.
XA	4,000–4,525 and 2d and 3d harmonics
XC	4,000–4,525 and 2d harmonic.

In addition to the above, this ambitious program included:

Duplexing the radio installations in seven battleships, three cruisers and eight auxilliaries.

Installation of break keys and the improvement of radio direction-finder installations and the provision of auxiliary power source for emergency transmitters on all destroyers.

Fitting all submarines with coil antennas.

Provision of field strength and antenna measuring instruments to all ships.

Provision of battery-charging equipment to all ships.

Service tests of experimental 5-kw, high-frequency and 5-kw. continuous-wave intermediate-frequency transmitters on designated ships.

Provision of trap units for receiver installations on all duplexed ships.

Provision of crystal-controlled frequency indicators for models TV, TW, and TX transmitters and model RF receiver.[19]

The program rejected the recommendation of the Commander in Chief, U.S. Fleet, concerning the upper limitation of frequency usage to 9 mc. Equipments capable of working on frequencies up to 19 mc. were made part of the requirements. In support of this program for the fiscal year 1926, Congress approriated $550,000.[20] This sum was far more in keeping with the amount which could be spent than the previously appropriated $1½ million, much of which lapsed. The equipment in the above table was placed under contract.

Hooper had been relieved as Fleet Radio Officer by Comdr. H. P. LeClair, USN, in late 1925, and had been assigned temporary duty in the Office of the Director, Naval Communications, to assist McLean in preparation for the forthcoming Fourth International Radio Conference to be held in Washington in 1926. In March 1926 he again became Head of the Radio Division, Bureau of Ships, relieving McNeely. By this time the radio modernization program had advanced considerably as compared to its condition in June 1924 when he wrote the previously mentioned terse letter to McNeely. However, he believed it should proceed at a faster rate. He was not so adverse to the use of the higher frequencies as he was to abandoning the low frequencies until the use of medium and high frequencies had proved reliable.

PROBLEMS OF IMPLEMENTATION AND CHANGES IN PLAN

One of his first actions was an investigation of the radio research situation. He found that the Naval Research Laboratory was engaged in the construction of 11 XA high-frequency transmitters and was operating several high-frequency circuits for the Naval Communication System. He objected to this departure from research to manufacture and operation. On 27 October he directed the head of the Research Section to transfer all operating equipment from the Laboratory to the Naval Radio Station, Arlington, and to direct the immediate cessation of all manufacturing except design models by the Laboratory. He directed that all conferences on designs, research and development, and contracts be held in the Bureau, and prohibited the Laboratory from handling publicity on Bureau radio research projects. To control the work on radio research he established a priority list and required the Laboratory to make monthly progress and expenditure reports. Exchange of information with other Government and private laboratories was made mandatory.[21] In order to accomplish the latter, Hooper arranged for a conference with the responsible heads of the Radio Corp. of America, the General Electric Co., and the Westinghouse Electric & Manufacturing Co., which was held in New York on 11 November 1926. Representatives of the Naval Research Laboratory were not present at this meeting. In this conference the Radio Corp. of America and its corporate partners were unable to arrive at a method of exchanging research information because the Navy allowed its research personnel to patent and sell their developments in all cases where security was not violated. The commercial

[19] Ibid., May–June 1926.

[20] The Washington Star, 10 Jan. 1925.

[21] Memorandum, dated 27 Oct. 1926, Hooper to Research Section.

companies took the position that their developments would be endangered. As a result a committee was established to find a cross-licensing basis for cooperation.[22] Several years passed before this was accomplished.

Another of Hooper's initial actions upon returning to the Radio Desk was to recommend a change which limited the installation of high-frequency transmitters in the fleet to the following ships:

Flagships of units requiring long-distance communications.
Light cruisers, first line.
Minelayers, first line.
Destroyer leaders.
Fleet and minelaying submarines.
Large patrol vessels.
Vessels on special service, when authorized.

This policy was approved on 31 March 1927 by the Chief of Naval Operations.[23]

In a lengthy letter to LeClair, dated 20 July 1926, Hooper summed up the fleet communications situation and advised him not to adopt a fleet frequency plan, which would require ships to shift frequencies during tactical evolutions, because of the prohibitive costs of crystals which would be required by such a plan and also because it would endanger the reliability of communications by increasing the likelihood of unit and force commanders losing contact with their ships.[24]

He continued, stating that equipment necessary for vacating the broadcast bands would be available during the year for surface ships but not for spotting aircraft, since the problem of receiving through ignition noises in the 3–4-mc. band was still unsolved.

In commenting on the high-frequency transmitters for the five major flagships, he stated that they should be delivered within the next few months and recommended that they be used for communications between the Commander in Chief and his four major force commanders, for intercommunication between these four force commanders when widely separated, and for communications between those flagships, and the Navy Department and naval districts. He urged that the operation of these transmitters be developed as early as practicable in order that it might be determined whether the use of high frequencies should be further expanded within the U.S. Fleet. He reexpressed his grave and persistent concern over the ability of some ships to receive above 9 mc. because of internally generated disturbances.

Continuing, he explained his reluctance in supporting the use of high frequencies, stating that an enemy quickly could build, at distant locations, low-powered high-frequency transmitters capable of creating sufficient interference to disrupt fleet communications. Further, Hooper reminded LeClair that only low frequencies carried, by day, the distances required by the Navy General Board, and that should high frequency not be satisfactory during daylight, it would still be necessary to install low-frequency vacuum tube transmitters in flagships and cruisers. He deplored the misinformation circulated about the marvelous feats accomplished in long-distance communications on high frequencies and the fact that radio personnel had been encourged to construct "haywire" high-fre-

[22] Minutes of meeting, dated 15 Nov. 1926, between representatives of the Navy Department, the Radio Corp. of America, the General Electric Co., and the Westinghouse Electric & Manufacturing Co.

[23] Bureau of Engineering Monthly Radio and Sound Report, July–August 1927, pp. 18–19.

[24] Hooper was correct in his opinion of that time. Later, such a fleet frequency plan became necessary, but this was after transmitters could be kept on frequency without crystals. The great weakness in such a plan at that time was in the failure of the officer of the deck to inform the communication officer or his assistants that an evolution had been directed which would change the ship's position in the cruising or battle disposition. From experience in the several years prior to and at the beginning of World War II, the writer found it necessary to keep close by the conning station when evolutions were probable. This resulted in his becoming, as did the communication officers of many large ships, the ship's tactical officer. Still later, when the ship's organization was changed to include an operations division, of which communications became a part, and the installation of the combat information center through which all information flowed, this problem ceased to exist.

quency transmitters which at best worked only under ideal conditions.

After completing this expostulation, he admitted that the performance of the Naval Research Laboratory XA transmitter installed in the U.S.S. *Memphis* indicated that high frequency is a desirable asset for flagship long-distance communications, and for that purpose the installations in the U.S.S. *California* and U.S.S. *Texas* should proceed without further delay.[25]

The Laboratory personnel did not take kindly to Hooper's intrusion. In early 1927 the forwarded a memorandum of complaints to the Chief of the Bureau of Engineering which was routed to Hooper for comment. On 20 March 1927 he replied to their complaints by memorandum. This stated that in March 1926 he had thoroughly analyzed the work necessary to complete the radio modernization program and had reached the conclusion that there was little hope of completing it unless more technicians were made available to the Laboratory and two-thirds of the problems contracted for solution with private companies. All design problems and the money expended on them must be carefully scrutinized. He suggested that the Chief of the Bureau direct the Director, Naval Research Laboratory, to indoctrinate his personnel with a spirit of understanding and loyalty and to plan to insure that there be no continuance of the feeling of disloyalty and lack of confidence evidenced by their memorandum. He reiterated the instructions given his subordinates, and closed with a scathing denunciation of the manner in which the Laboratory was being conducted.

One of the main objections made by Laboratory personnel was the requirement that they exchange information with engineers of commercial companies, since this would reduce the possibility of financial gain by the individual for his work. Hooper agreed that this was a natural fear and objection, and that if the Bureau desired to retain the highest type of research personnel it was necessary to countenance the existent patent-selling system or to obtain funds from Congress for raising their salaries to a point compatible with that paid by industry.[26]

Much can be written about both sides of this "revolt." Later events prove that the loyalty of the Laboratory personnel was unquestionable. Under McNeeley, undoubtedly, they had had too much hand in the establishment of policy and had worked almost exclusively on what they considered best for the Navy. The dedicated ones had remained with Laboratory despite the fact that they, like all other Government personnel of that period, were underpaid. Most of them could have found more gainful employment. Following the war, the Government had encouraged them to patent and sell their inventions, and they took advantage of this to augment their salaries and thus provide their families with a living income.

Hooper, however, was not one to seek or take advice upon radio matters as they concerned the Navy. To himself, he constituted final authority on such matters. Insofar as he was concerned there was no "court of appeal." [27] There can be no doubt that a firmer control over the work of the Laboratory was necessary.

The records indicate that Hooper was able to maintain his position. The Bureau began the actual assignment of projects and priorities, and the Laboratory made monthly reports of progress and expenditures. Laboratory operation of radio circuits and

[25] Letter, dated 20 July 1926, S. C. Hooper to H. P. LeClair.

[26] Memorandum, dated 20 Mar. 1927, Hooper to the Chief of the Bureau of Engineering.

[27] "In my opinion Hooper adapted the policy of making communications the whipping boy for all that went wrong in the fleet, and he did this deliberately . . . I could never do anything right when I worked for him, and put in many long hours doing letters over and over until he finally signed them. He never gave me an unsatisfactory Report on Fitness, but they were surely mediocre ones. In spite of this, I still think he was the outstanding person in the business." Letter, dated 22 Jan. 1959, Rear Adm. R. E. Melling, USN (retired), to the author.

manufacture of equipments were discontinued.[28]

Despite Hooper's pessimism, rapid strides were made in improving the radio installations in the Fleet and at the shore stations during 1927 and 1928. Many new low- and intermediate-frequency tube transmitters of both low and high power were developed by the three major electric companies, and the Naval Research Laboratory developed several low-power high-frequency transmitters for various ship types and shore stations. The latter required crystal control of the basic frequency and frequency doubling or tripling for the harmonics. This limited the numbers of frequencies available, depending upon the number of crystals provided. Satisfactory multiplexing was developed and installed to permit a great reduction in shipboard antennas. By the middle of 1928, almost all of the major ships had been duplexed, and the old arc and spark transmitters had become museum equipments. The models RE, RF, and RG receivers were still standard Navy equipment because of their ruggedness and simplicity, although rapid advances in the art of receiver design and construction had been made by the commercial companies in the endeavor to dominate the enormous demand for home receivers for broadcast purpose. There were requests from the Fleet for more modern receivers powered by alternating current, but the more immediate demands for other equipments necessitated the retention of these types, of which over 1,000 were in use.[29]

At this time, with the modernization program proceeding as rapidly as funds would permit, Hooper became the Director of Naval Communications. He was relieved of his Bureau of Engineering duties by Comdr. E. C. Raguet, USN. His contemporaries have given him the major credit for the efficiency of radio communications in the Navy. In a large measure they are correct, but great credit is also due McNeeley. Prior to going to sea in 1923, Hooper only partially understood the magnitude of the program and understood it more fully only after facing the problems as they existed in the Fleet. McNeeley developed an excellent plan under rapidly changing conditions and was responsible for its initial execution.

[28] Bureau of Engineering Monthly Radio and Sound Reports subsequent to June 1927.

[29] Ibid., July–August 1927, p. 24.

REVISION OF THE 1926 MODERNIZATION PLAN

Fleet demands for communication channels steadily increased causing a demand for more and more equipment. This in turn, called for more compact design and the utilization of lighter weight materials. Recognizing the necessity of modifying the 1926 modernization program to meet the increased requirements, the Bureau of Engineering began revising it early in 1929, giving consideration to the following:

Fleet requirements for communication channels;

Individual ship requirements for communication channels;

Intercommunication requirements between all types of naval ships and aircraft and naval shore radio stations, foreign radio shore stations, U.S. Army, and merchant marine;

Wartime utilization of the regular merchant-ship radio installations;

Standardization of equipment to facilitate maintenance and for economy in providing spare parts;

Probable grouping of ships in task forces and groups;

The fleet radio frequency plan;

The report of the Ship Control Boardl;

National and international laws and regulations and treaties pertaining to radio, navigation, and safety of life at sea;

U.S. Army and Coast Guard radio plans;

Space, weight, and personnel limitations aboard ship;

Technical design limitations; and

The use of radio by foreign navies.

This revision was approved by the Chief of Naval Operations on 1 June 1929 and, with modifications due to improved equipments, remained the primary guidance for ship's radio installations until the beginning of World War II. The necessity of providing high-frequency radio communications to all combatant vessels of the Fleet was recognized for the first time.[30]

[31] This did not apply to small patrol and other craft operating under the commandants of naval districts.

Again, as in 1926, an ambitious program in support of the revised plan was immediately undertaken. During fiscal year 1930 the following were completed:

50 models TAF–2, TAO, TAR, TAR–2, and XF–1 high-frequency transmitters were installed in battleships, aircraft carriers, light cruisers, fleet submarines, and destroyer tenders;

119 models TU–4, TAH, TAJ–1, TAP, TAQ, and TAQ–1 low-frequency transmitters were installed in battleships, aircraft carriers, aircraft tenders, light cruisers, destroyers, submarines, survey vessels, and various types of tenders, tankers, and supply vessels;

41 models TAD–1, TAD–2, TAP, and TAT medium-frequency transmitters were installed in battleships, aircraft carriers, destroyers, minesweepers, tenders, and other supply vessels;

49 models TAV and TAV–1 medium-frequency portable field transmitters were issued to major units of the fleet;

20 RO-RP low-, medium-, and high-frequency receivers were fitted in submarines;

15 RQ (15–20,000) kcs. receivers were fitted in minesweepers;

30 DG radio direction finders were installed in battleships, light cruisers, and auxiliaries; and

Major fleet units were provided with Model LB heterodyne frequency indicators and crystal-controlled calibrators.

In addition, the duplexing or modernization of the radio installations of the U.S.S. *California, Oklahoma, Nevada, Tennessee, Arizona, Pennsylvania,* and *Vestal* were completed. Complete radio installations for 34 "S" type submarines, direction-finder equipment for 82 destroyers anl auxiliaries, and Model TAK transmitters for 8 battleships were installed. Fifteen TAQ–2, 1 TAR–1, 33 TAR–2, 30 TAT–1, and 3 XP–1 transmitters were purchased during the fiscal year for ship's installations. Other projects were completed to improve efficiency and flexibility.[31] The replacement of the destroyers of two squadrons by destroyers from the reserve fleet facilitated the modernization of their radio installations. More was accomplished toward the provision of adequate, flexible, reliable fleet communications during the 1930 fiscal year than during any other like period of time.

The annual report of the Commander in Chief, U.S. Fleet, for the fiscal year 1930, acknowledged the great improvement in radio communications. It stressed the need of new receivers and requested their provision as soon as practicable.

A study of the Bureau's contracts for receivers indicates that improvements in these equipments were lagging those of transmitters. Following the development of the models RE, RF, and RG receivers only models RO, RP, RQ, and RT had been developed for shipboard usage. The situation was recognized, and in 1930 the Naval Research Laboratory was directed to design and develop the RAC low-frequency barrage receiving equipment for short stations. Following the completion of the design and development of the RAC., the Radio Corp. of America-Victor Co. was, in fiscal year 1931, given a contract for the design, development, and manufacture of 227 Model RAA (910–1000 kc.) and 163 Model RAB (1–30 mc.) receivers. These were the Navy's first alternating current receivers and were of the superheteroydne type with single-dial tuning and were purchased for usage afloat and ashore. They were installed during fiscal year 1932.

While fleet radio equipment was being modernized, a similar program was carried out at the shore radio stations. Models TAB–3, TAD–2, TAF–2, TAJ–1, TAL, TAQ, TAQ–1, TAS, and TAT were installed as required in these stations. In fiscal year 1930, 9 TAB–4, 2 TAW, 10 TAY, and 13 XJ–2 were purchased specifically for shore stations.

Following delivery fo the models RAA and RAB receivers and the concurrent issue of models TAU, TAZ, TBA, TBB, and TBC transmitters which were purchased during the fiscal year 1931, the U.S. Navy possessed the most modern and efficient radio system of any navy. In the following years there was development of automatic high-speed equipment, but too little was done toward continually improving the system, with the result that when World War II began our transmitting and receiving equipment was rapidly becoming obsolete.

[32] Bureau of Engineering, Monthly Radio and Sound Report, July–August–September 1929.

CHAPTER XXXVI

United States Navy Administration of Electronics

PROLOG

For several years following World War I, electronics in the Navy continued to be primarily limited to radio, with material and budgetary control centered in the Bureau of Steam Engineering [1] in a Radio Division which was established in 1903. Its operational use, under the Chief of Naval Operations and directed by Director, Naval Communications, remained almost limited to an extension of landline telegraphic circuits. Its use for tactical and strategical purposes was not looked upon highly by those in command. A fairly reliable shore radio system covering our shorelines and connecting us with our territories and possessions had been established, but its use in the Fleet had remained limited. During World War I efforts had been made to utilize electronic principles in sonar, pilotless aircraft, and remote control of torpedoes, but little success was attained.

Naval radio and sound research activities were consolidated at the Naval Research Station, Anacostia, D.C., in 1923. Previous to that time, radio research had been conducted by the Naval Radio Laboratory under Dr. L. W. Austin at the Bureau of Standards, the Radio Test Shop of the Washington Navy Yard under Lt. W. A. Eaton, USN, and the Naval Aircraft Laboratory under Lt. Comdr. A. Hoyt Taylor. Taylor became head of the consolidated activity. Sound research was moved from New London, Conn., to Annapolis, Md., following the termination of World War I hostilities. Later, with the establishment of the Laboratory at Anacostia they were transferred there under the direction of Dr. H. C. Hayes.

The development of pilotless aircraft was commenced under contract with the Sperry Gyroscope Co. at Amityville, Long Island, but after the conclusion of World War I this work was transferred to the Naval Proving Ground, Dahlgren, Va., and carried out by naval personnel under the supervision of the Bureau of Ordnance with the assistance of the Bureau of Engineering. Interest lagged in the project and its active development temporarily ceased in 1926.

The development of the radio-controlled torpedo, initially the interest of the Coast Artillery Corps, U.S. Army, was commenced just prior to World War I. When active work began on this project it was supervised by a joint board, and conducted under contract by John Hays Hammond, Jr. Following the close of the war the Army ceased to be interested. The project was transferred to the Navy and was carried to a successful conclusion, but no practical application of its use was immediately made insofar as the torpedo was concerned. The principles developed were utilized in the development of equipment for remote radio control of surface vessels and aircraft. Under naval jurisdiction this project was also under the cognizance of the Bureau of Ordnance with the technical assistance of the Bureau of Engineering.

Changing concepts of naval operations resulted in a reorganization of our naval

[1] The title of the Bureau of Steam Engineering was changed to the Bureau of Engineering on 4 June 1920. This had no effect upon the organization of the Bureau.

forces in 1923, at which time the U.S. Fleet was formed. These new concepts necessitated increased uses of radio which far exceeded the capabilities of the medium. These increased requirements called for multiple transmission and reception by individual ships. The ship installations were not capable of this with any degree of reliability.

Radio had never been understood by the majority of the senior officers, and they took little interest in it. Junior officers shied from duty assignments in communications, for little credit was given when they conducted satisfactory communications and when they could not, which happened more often than the former, they were subject to disdain. One of the first requirements necessary in broadening fleet radio communications was building up a fleet radio organization of capable and qualified personnel. To accomplish this, Hooper was ordered to sea in July 1923, as Fleet Radio Officer, relieving Lt. T. A. M. Craven, USN. Capt. R. W. McNeely, USN, became Head of the Radio Division, and Craven became his assistant for ship's installations.

ORGANIZATION AND ADMINISTRATION OF FLEET COMMUNICATIONS

Prior to the assignment of Hooper as Atlantic Fleet Radio Officer in 1912, there had been no specific fleet organization for radio communications. As a result of this there had been little strategical and no tactical use made of this method of communication. Hooper convinced the Commander in Chief of the necessity of having officers assigned specific radio duties in individual ships. In the major units it was a full-time assignment, while in the smaller ones it was a corollary duty. Following the improvements affected in the Atlantic Fleet radio discipline, all fleet and forces were assigned radio officers.

After the outbreak of World War I further steps were taken to strengthen the fleet radio organization. "U.S. Naval Communications Regulations, 1918," promulgated by Secretary Daniels on 1 April 1918, consolidated all previous orders and regulations. All commands were required to have a communication officer responsible for all means of communication, including the handling and routing of mail. In the case of flagships, this function was normally assigned the flag secretary, but a flag officer could designate any officer of his staff to perform this duty. In addition to the communication officer, all commands were required to designate radio officers and signal officers as assistants to the communication officer. Major commands were required to assign additional officers for purposes of watchstanding and coding. Radio gunners were provided for maintenance of equipment.

The "U.S. Naval Communications Regulations, 1918," prescribed the specific duties of these officers. Excerpts of the duties of radio officers are quoted:

> Staff radio officers are just as much responsible for the radio of all ships under their particular flag officer's command as they are for the radio of their own flagship. They shall make frequent inspections, tests of material and examination of personnel of all ships under their flag officer's command;
>
> All radio officers will familiarize themselves with the general organization and operation of the communication service and with the instructions that may be issued from time to time in regard to them;
>
> Fleet, force, division, and flotilla radio officers, and radio officer of battleships, first-class cruisers, destroyer division flagships, and submarine tenders shall be qualified operators;
>
> On ships for which qualified officer operators have not been assigned, one of the ship's officers, preferably a watch officer, shall be assigned as radio officer, in addition to his other duties, and will be in charge of the administration of the radio office and responsible for the radio service and radio material of the ship, and may in some cases also be the communication officer;
>
> Radio officers of first-rate ships shall not be assigned to any other station, and shall perform no other duty than that of radio officer, except at fire and collision quarters. He shall be on duty at least six hours daily in the radio signal station. In addition he shall be responsible for the efficiency of the radio force, and further the observance of the regulations and instructions relating thereto, and to this

end he shall exercise constant surveillance over the operators and shall inspect radio record books;

The officer to be detailed as ship's radio officer shall be notified in advance of his detail as such, and shall be required to train himself and become sufficiently proficient to take a regular watch. Upon assuming duty as radio officer, he shall be relieved of all other duties. This officer shall be placed on watch two months after assuming this duty, and shall take the watch prescribed by the force commander. A regular operator may listen in additionally to assist this officer in receiving, but the radio officer shall do all sending during the time he is on watch when this does not delay communication;

The ship's radio officer is responsible for the care and efficient operation of the ship's portable radio set. He shall drill all members of the crew of this set and shall take charge of the set and land with it when the ship's battalion acting singly lands for service. He shall calibrate the portable set for the various tunes to be used and shall have his crews so instructed in the operation of the set that it may be landed and operated at any time without delay;

The radio officer of the flagship of the torpedo flotilla shall be attached to the staff of the flotilla commander for duty as flotilla radio officer. The radio officer on each torpedo division flag boat and submarine tender shall act as radio officer of those divisions;

In the absence of a radio officer on the staff of a squadron or division commander the radio officer of the flagship shall be directly under the authority of the flag officer and shall act as squadron or division radio officer;

The radio force attached to the fleet flagsbip shall be under the immediate direction of the fleet radio officer, and similarly the radio force of a force or division flagship shall be under the immediate direction of the force or division radio officer; and,

A tendency of radio operators to become lax in military habits exists, due to the way of these men living apart, to a certain extent, from the crew. Radio officers should be required to instruct operators, with a view of correcting this.

NAVAL COMMUNICATIONS POLICY AND MISSION

The United States emerged from World War I as one of the most important world powers. The support of our foreign policy necessitated the Navy showing the flag in various troubled areas such as the Mediterranean, the Caribbean, and the Asiatic areas. To provide the commanders of our forces in these areas with information upon which to base decisions, the Secretary of the Navy on 1 December 1922, issued a paper entitled "United States Naval Policy." This contained the following provisions with regard to communications:

The maintenance and operation of a naval communication system based on the requirements of the forces afloat in a campaign in either or both oceans;

The provision of adequate communication facilities to mariners along the United States coasts were privately owned facilities are not made available;

The promotion of harmony and cooperation between naval radio facilities and all other radio systems and the areas of their activities;

The safeguarding of the radio and cable interests of the United States;

The provision and operation of radio direction finder stations as required;

The development and coordination of all systems and methods of communication which efficiently transmit information;

The development of the uses of all forms of communication in the fleet necessary for increased battle efficiency; and,

The use of the naval radio communication system in time of peace to assist in the development of American interests abroad.

In consonance with this policy the following was prescribed:

The mission of the Naval Communication Service is to afford efficient communication for our fleets. This includes furnishing accurate and rapid communication, secret if necessary, within the fleets, and between the fleets, the Navy Department, the shore bases, outlying possessions, the merchant marine, our own nationals, friendly or allied vessels, and friendly or allied nationals. The system for accomplishing this is capable of a number of subsidiary uses. This fact has caused the establishment of a number of special services, such as direct communication with some foreign capitals; transmission of press news; provision of commercial facilities where private facilities are inadequate or do not exist; aids to mariners, such as time signals, hurricane and storm warnings, weather forecasts, hydrographic reports, distress reports and radio direction finder services; and, handling of messages for other government departments as a measure of national economy.[2]

The issuance of naval policy and the establishing of the mission of naval communications necessitated a complete revision of the communications regulations. This

[2] "Communication Instructions, U.S. Navy," Washington, Government Printing Office, 1925, p. 14.

was done under the supervision of Capt. Ridley McLean, USN, Director, Naval Communications. They were promulgated by the Chief of Naval Operations on 9 March 1925 as "Communication Instructions, U.S. Navy, 1925."

COMMUNICATIONS AND ELECTRONICS ORGANIZATIONS, 1925–39

The "Communication Instructions, U.S. Navy, 1925," were broader in scope, less specific in detail, than the "U.S. Communications Regulations, 1918." The general responsibilities for communications were delineated. The Naval Communication Service was to be administered under the Secretary of the Navy, by the Chief of Naval Operation, through the commandants of naval districts, commanding officers of shore stations and other shore activities, including naval attachés abroad, and through the Commanders in Chief, U.S. and Asiatic Fleets, commanders of forces, squadrons and other units, and commanding officers of vessels afloat. To provide this administration the Chief of Naval Operations was assigned an officer, designated the Director of Naval Communications, who, in turn, was assisted by a staff. Heretofore the personnel of the Naval Communication Service had been administered by the Office of the Director. By this change their administration became a function of the Bureau of Navigation, at that time charged with the administration of all naval personnel. The development, provision, and maintenance of electronics equipment and the budgetary support of the Naval Communication Service continued a function of the Bureau of Engineering. At this time the Bureaus of Ordnance and Aeronautics had practically ceased to have interest in the application of radio to control torpedoes and aircraft and had no electronics organization.

Between 1925 and 1939 only minor changes were made in the electronics organization. The world economic situation of the early thirties resulted in reduced military appropriations and the Bureau was able to handle only the most urgent of the electronic material needs of the moment. Research and development was reduced to the most urgent requirements such as radar, sonar, and the development of radio-controlled aircraft and limited-range voice radio equipments. Since industry was likewise affected by the depression, practically no research was conducted to improve normal radio communication apparatus. By 1939 the excellent equipment which had been provided following the approval of the 1929 modernization plan was obsolescent. The personnel of the Radio Division had been reduced to the bare minimum necessary to handle the urgent day-to-day administration, and they were not in a position to generate plans for improvements. During this period the Radio Division was administered by the following officers:

Comdr. S. C. Hooper, USN, March 1926–July 1928
Comdr. E. C. Raquet, USN, July 1928–December 1930
Comdr. S. A. Manahan, USN, December 1930–October 1930
Comdr. W. J. Ruble, USN, October 1933–June 1938
Lt. Comdr. J. B. Dow, USN, June 1938–January 1940

During the same period the Naval Communication Service continued to be administered and operated under several successive directors based on the "Communication Instruction, 1925," as amended slightly from time to time. The several directors during the period 1925-39 were:

Capt. Ridley McLean, USN, June 1924–June 1927
Capt. T. T. Craven, USN, June 1927–August 1928
Capt. S. C. Hooper, USN, August 1928–July 1935
Rear Admiral C. E. Courtney, USN, July 1935–July 1937
Capt. Leigh Noyes, USN, July 1937

The reduction in naval personnel strengths following the treaty on the limitation of arms and continuing on through the depression years placed a heavy burden on naval communications. During 30 years service, mostly in communications, the author has had ample opportunities to note that reductions in personnel without commensurate reductions in naval tonnage and functions always sharply increased the volume of radio traffic. This is the result of personnel not being able to timely perform their duties and because of the lack of sufficient clerical personnel. When units of the fleet put to sea, officers had better opportunity to catch up with their work, and since correspondence would be delayed in mailing until arrival, the use of radio for administrative and logistic purposes was greatly increased. Even in port this condition existed to a lesser extent because of lack of stenographic assistance. This situation has never been understood by the Navy personnel management which has normally insisted upon "across-the-board" cuts following personnel reductions. This has always compounded the problems of communication personnel.

The handling of the ever-increasing volume of radio communications necessitated improved efficiency on the part of all communications personnel. The communication requirements in battle efficiency competition were increased. These requirements were based more upon the capability of handling large volumes of traffic with minimum of error, than upon proper wartime usage. Hooper, always in position to more or less dictate these requirements, was insistent that all radio officers be qualified operators. This questionable requirement did much to discourage officer interest in naval communications. Despite the fact that communication efficiency was an integral part of the battle efficiency competition, most commanding and executive officers continued to consider it a service rather than a weapons system, made no concerted effort to reduce the number of messages originated by their officers, and normally assigned officer personnel to it after the gunnery and engineering officers had had their choices of newly reporting officers. The practice of using radio personnel for extraneous duties became so universal that it necessitated the issuance of a departmental order prohibiting such action.

ELECTRONIC ORGANIZATION OF THE BUREAU OF SHIPS DURING WORLD WAR II

In June 1940 the two ship Bureaus, Engineering and Construction and Repair, were consolidated into a single Bureau of Ships. Failing to envision the rapid electronic developments which were to ensue in the next several years, the responsibility for radio and sound was assigned to a Radio and Sound Branch of the Design Division. The developments in electronics during 1940 and 1941 placed this organization under a heavy strain. The radar development program was nearing completion, and radar cognizance was about to be transferred from the Special Development Section to the Radio and Sound Branch. It appeared that it would be necessary to establish a separate unit in that Branch since it required new skills. Fleet personnel were not trained in its use, navy yard technicians lacked installation knowledge and experience, and contractors did not know how to engineer and produce it nor were they capable of estimating its production costs.[3]

When the transfer of cognizance was made the personnel who had been responsbile for radar development were also transferred, and a separate unit was established which handled radar design, procurement, installation, maintenance, and training.

The declaration of a limited emergency accelerated the electronic procurement and installation plan. New military characteristics were established, specifications for production were drawn, and ships' allowances were determined. From the latter, estimated requirements were calculated and

[3] "An Administrative History of the Bureau Ships During World War II," unpublished and undated draft narrative prepared by the Historical Section Bureau of Ships pp. 238–239.

the Bureau of Supplies and Accounts was requested to procure the equipments by competitive biddings of manufacturers who were approved by the Bureau of Ships. The existence of a completely separate radar unit resulted in a lack of consolidated procurement effort, which, in turn, established undesirable competition for the services of manufacturers. However, this organization continued to function until late in 1942, first under Spriggs and then under Dow, who relieved him in December 1941 after having spent the better part of a year studying British radar developments.[4]

The rapidly expanding scope of electronics activity and the unwieldly organization with which it was being conducted necessitated the reestablishment of a Radio and Sound Division in October 1942. This functional organization consisted of a Design Branch, a Procurement and Production Branch, an Installation and Maintenance Branch, and an Aircraft Radio Branch. This brought together the various personnel who possessed similar talent and training, standardized electronic research, consolidated field staffs, and aided in coordinating procurement.

The Design Branch prepared design and performance characteristics from military characteristics (which they assisted the Office of the Chief of Naval Operations in providing), established manufacturing specifications, and initiated and coordinated design and development of all electronics equipment other than that under the cognizance of the Bureau of Ordnance. The Procurement and Production Branch was responsible for procurement and distribution of all electronic material and for expediting its manufacture. Increased technical complexity and rapid developments, combined with accelerated procurement and lack of qualified technical personnel in the Bureau of Supplies and Accounts, made it necessary that this Branch assume the responsibility for contracting for electronic material, subject only to the legal approval of the contracts by that Bureau. The Installation and Maintenance Branch determined type allowances and worked with the various ship-type sections of the Bureau of Ships to provide for proper installation and maintenance. Additionally this Branch had cognizance of the naval district electronic material officers and the manufacturers' field groups. It coordinated electronics publications and the curricula of electronics schools. The Aircraft Radio Branch was responsible for radar and communication equipment for aircraft.[5]

Basically this organization operated with only minor changes until mid-1944 when it was retitled the Electronics Division. At that time, because of severe criticism of the electronic procurement program, the responsibility for procurement was transferred to the Contract Division of the Bureau of Ships. The functions of progressing, expediting, and aiding manufacturers to procure labor and material were assigned to a newly established Equipment Branch. The Procurement and Production Branch was disestablished and its personnel were reassigned either to the Contract Division or to the Equipment Branch. Following this there were no further major changes in this organization for the remainder of the wartime period.

ORGANIZATION OF BUREAU OF AERONAUTICS ELECTRONICS

When the Bureau of Aeronautics was established in 1921 it was assigned, among other functions, the task of design and procurement of aircraft and aircraft equipments. These had formerly been functions of the Bureau of Engineering. The new Bureau had no personnel sufficiently familiar with radio to assume these functions, and they were continued in the Bureau of Engineering with the Bureau of Aeronautics providing them with one naval aviator, responsible to the Chief of the Bureau of Aeronautics.[6]

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[4] Ibid.

[5] Ibid., pp. 247–248.

[6] Letter, dated 1 Nov. 1944, Bureau of Aeronautics file Aer–3–310–IHG.

On 18 November 1925, a radio desk was established in the Scientific Group, Design Branch, Material Division of the Bureau of Aeronautics. It continued as a single desk until August 1931, when it became a section directly under the supervision of the head of the Design Branch. In April 1932 radio interference generated by the ignition and electrical systems of aircraft prompted the Radio Section to point out the need for having cognizance over the entire electrical plant. This was approved and the section was retitled the Radio and Electrical Section.[7]

In 1934 the Bureau of Engineering purchased some radio equipment for aircraft without obtaining the approval of the Bureau of Aeronautics. At about the same time the Bureau of Engineering endeavored to obtain direct control of appropriations for the purchase of aircraft radio material. These two actions brought into the open a growing conflict between the two Bureaus concerning cognizance over aircraft radio equipment. The differences were settled by conferences between the Chiefs of the two Bureaus, and a joint letter defining the responsibilities of each Bureau in this field was drafted and signed. It provided that the Bureau of Aeronautics would initiate all aircraft radio equipment procurement requests, that the Bureau of Engineering would issue the requisitions and select the contractors subject to the approval of the Bureau of Aeronautics.[8]

In 1936 this question of cognizance was reopened following further indications on the part of the Bureau of Engineering that it desired to assume complete control. The Chief of the Bureau of Aeronautics, in a letter to the Secretary of the Navy, pointed out that lack of trained officers had prevented the Bureau from assuming the responsibility for aircraft radio installations upon its establishment, but that this condition no longer existed. He maintained that the Bureau of Aeronautics should have complete control of aircraft radio, since it had become a specialized area—an integral part of the airplane, and thus limited in size and weight, requiring special design considerations and involving peculiar problems of installation, maintenance, and operation. This letter was referred to the Navy General Board, where opposition from the Bureau of Engineering succeeded in preventing a complete transfer of cognizance. However, a revised joint agreement was reached which gave the Bureau of Engineering the responsibility for research, design, development, preparation of specifications, and contracting, provided these met the aproval of the Bureau of Aeronautics. The latter Bureau was to define the policies, subject to the approval of the Office of the Chief of Naval Operations, and was to provide the Bureau of Engineering with specific items upon which research and development were desired. The direct charges entailed in this were to be borne by the Bureau of Aeronautics. This agreement was approved by the Secretary of the Navy.[9]

Following this action, the Bureau of Engineering established an Aviation Radio Section in the Radio and Sound Division. This was staffed with one naval aviator, having dual responsibilities to both Bureaus, and four radio engineers. At this time there were seven officers and engineers attached to the Radio and Electrical Section in the Bureau of Aeronautics.[10]

With the advent of the war in Europe, it became apparent that the preparedness program would necessitate an expansion of the Radio and Electrical Section, and additional engineers were procured. By 1940 six additional officers and engineers had been assigned to it.

In 1940, preliminary to an anticipated major expansion, the question of assuming the entire cognizance of aircraft radio was again raised. It was proposed that the Bureau of Ships Aircraft Radio Section be

[7] Ibid.

[8] Letter, dated 22 Oct. 1934, Bureau of Aeronautics file Aer–E–31–FAM, F–42.

[9] Letter, dated 31 Dec. 1936, Bureau of Engineering file F42–1 (12–31–W).

[10] Letter, dated 1 Nov. 1944, Bureau of Aeronautics file Aer.–3–310–IHG.

assimilated by the Bureau of Aeronautics. The move at that time was considered simple since the section consisted only of one lieutenant, four engineers, and one clerk. The proposed move received favorable consideration by higher authority in the Bureau of Aeronautics, but was opposed by the Bureau of Ships. A fundamental basis for opposition was the apparent possible duplication of effort and the feeling that centralization of radio engineering talent in the Bureau of Ships was most economical of personnel. The Bureau of Aeronautics did not push the issue and no change was made.[11]

On 24 April 1941, Lt. Comdr. G. H. B. Hall, USN, became Head of the Radio and Electrical Section, Bureau of Aeronautics. Hall, realizing the tremendous expansion that must take place and the many problems which had to be solved, immediately undertook the tremendous task of outlining the aviation radio and electrical organization the Navy would require in event of war. The period just prior to the war was occupied with the establishment of policies upon which future development and programs of unprecedented scope were to be made. Representative of the increased importance attached to these plans was the total of $1,377,550 obtained for experiments and development of aircraft electronic and electrical equipment for the fiscal year beginning July 1941. This was a 330 percent increase over the estimates made in 1940 for the same fiscal year.[12]

It became apparent to Hall that his organization must be further increased by the addition of strong key men from the aviation radio industry who could form the nucleus for the much larger organization which would follow. In the period between August and October, 1941, three reserve officers and one civilian, all well qualified as aviation radio engineers, were added to his section. At this time Hall also pointed out the imminent need of the aeronautical organization for additional trained personnel in the field of radio and radar. He invited attention to available schools and recommended the training of communications officers, radio electricians, and two selected radiomen per squadron. He further recommended the setting up of an East Coast Fleet School for Radar Training. On 26, June 1941, he initiated action for the procurement and training of 50 ensigns for inspection and maintenance of radio, and electrical equipment, and this resulted in the detailing of officers to the new radar school at the Massachusetts Institute of Technology.[13]

On 1 May 1941, the Aircraft Radio Maintenance Section was established in the Maintenance Division, Bureau of Aeronautics, with the function of administering aircraft electronic maintenance. This relieved the Radio and Electric Section of these responsibilities.

The second major step along this same line was the recommendation on 11 October 1941 that the Production Division, Bureau of Aeronautics, establish a section to handle the quantity procurement of radio, radar, and accessories, which procurement was then being handled by Radio and Electric. This proposed section was also to handle the requests for necessary appropriations for production quantities of electrical and electronic equipment. This recommendation was approved, and in January 1942 the Production Division took over the electronic procurement function.[14]

A fundamental policy memorandum on aircraft radio and radar equipment was approved by Rear Adm. J. H. Towers, USN, Chief of the Bureau of Aeronautics, which covered complete policy on inspection, distribution, storage, and overhaul. It also set forth the fundamental policy that radio equipment should be installed by the airplane contractor instead of by the service. It also recommended that the installation of radar equipment initially be done by squadron personnel, but later be turned over to the airplane manufacturer when

[11] Ibid.
[12] Ibid.
[13] Ibid.
[14] Ibid.

the security classifications of the equipment could be reduced. This latter policy was put into effect in 1944. The policy of quality control test by the Naval Aircraft Factory of selected equipments out of the production lines was set up to replace the existing one of having all equipment delivered to that activity for test, final acceptance, and storage. The policy on spare equipments and their distribution was also covered.[15]

A policy of basing all estimates and procurement of radar and radio against specific classes and numbers of aircraft, rather than simply asking for pool stock quantities as had been the general practice, was adopted during October 1941. This made it far easier to obtain approval for the expenditure of such seemingly vast sums as contained in Radio and Electric Section request of 23 December 1951 for $27,654,000 for radar search equipment and $3,538,00 for IFF (identification, friend or foe), equipment.[16]

The entry of the United States into the war brought about a greatly increased acceleration of the aircraft construction program and increased the development of electronics of new and unknown potentialities. The Bureau of Aeronautics, for example, was to spend almost $5 million in fiscal 1943 for such development. This was three times greater than the amount expended for the same purpose during the preceding fiscal year. This required continuing expansion of the Radio and Electrical Section and an almost continuous reorganization. The problem of obtaining qualified personnel was a serious one which necessitated the Secretary of the Navy convening a special board in early 1942 in an endeavor to cope with the problem. This Board found that 489 key radar specialists were required by the Navy material bureaus, the Fleet, and the U.S. Naval Research Laboratory, and made the following recommendations: that radar specialists be procured and commissioned as reserve officers to meet the requirements as specified by the Bureaus; that reserve radar officers be indicated by a special designation; that in the case of radio engineers whose appointment was desired and recommended by material Bureaus, the nominal age limit be waived as may be deemed expedient; that the War and Navy Departments reach an agreement whereby neither service would commission a civilian employee of the other service without first obtaining a release; and that agreement be met with regard to rank given to newly commissioned radar specialists so that the standards of both services may be alike.[17] This report was approved by the Secretary of the Navy on 2 July 1942. He directed the Chief of Naval Personnel to take appropriate action necessary to carry out the recommendations.

During this period, the Radio and Electrical Section continued to divest itself of functions more properly belonging to the Maintenance and Production Divisions. On 3 February 1942, it was arranged that the Production and Maintenance Divisions would handle radar on the same basis that it handled radio. The Maintenance Division assumed its new responsibilities on 1 March 1943, and the Production Division began making radar procurements on 20 May of that year.

Early radar equipment was reaching the Fleet, and it soon became apparent that it was necessary to provide fleet personnel general information on aircraft radar characteristics. Aeronautics 55 was prepared in the Radio and Electrical Section and published as a confidential registered publication in April, 1942. This publication was continually revised and kept up to date.

To facilitate the installation of radar equipment, the policy of dividing radar equipment into groups of parts was evolved. A Bureau of Aeronautics letter to the Bureau of Ships, on 19 April 1942, requested that all contracts for radar provide for separation into three parts: Group A, consisting of plugs, shock mounts, and accessories to be delivered to the airplane

[15] Ibid.

[16] Ibid.

[17] Letter, dated 25 June 1942, Office of Chief of Naval Operations, file Op–23R/AB.

manufacturer for installation; group B, containing all confidential parts, basic equipment, components, instruction books, and operating spares; and group C, consisting of bulk spares. This became standard procedure and facilitated the program of having the airplane contractor install as much of the electronic equiment as possible consistent with security considerations and reduced the load on naval activities, which completed the installation by installing the group B parts.

The problem of cognizance of aircraft radio and radar equipment continued to plague the personnel of the Bureau of Aeronautics. On 22 September 1941 it was again recommended that cognizance be transferred completely to the Bureau of Aeronautics effective the first of July 1942. The proposal pointed out the advantages of direct control by the Bureau of Aeronautics over all phases of engineering, the provision of direct action by the Bureau instead of through the Bureau of Ships as intermediary, the closer coordination between design, production, installation, maintenance, and training that would result, the elimination of shipboard design concepts of weight, space and power requirements, and the elimination of joint control and duplication of paper work. It was pointed out that in June 1941, the Chief of the Bureau of Aeronautics had asked the Head of the Radio and Electrical Section if it was desirable for the Bureau of Aeronautics to assume greater control of aircraft radio and radar. Hall had stated at that time that the small Radio and Electrical Section could not take on the tremendous increase in work, but that as more personnel were obtained it might be well to do so. Towers had then stated, at a conference held by the Chief of Naval Operations to discuss transfer of fire control radar design and procurement from the Bureau of Ships to the Bureau of Ordnance, that the existing procedure for aircraft radio and radar was satisfactory for the immediate future, but that later developments might require similar action by the Bureau of Aeronautics. As a result of these and further discussions, and at the suggestion of Hall, the Assistant Chief of the Bureau of Aeronautics, in a memorandum to the Assistant Chief of the Bureau of Ships, suggested that representatives of the two Bureaus revise the existing joint letter on the subject of aircraft radio because of the development of a large number of new types of equipment which were more nearly an integral part of the airplane frame. Subsequent conferences evolved a revised joint letter which was approved by the Secretary of the Navy on 4 December 1942. No basic changes in cognizance were made but the previous joint agreement was clarified and amplified. A significant point made clear, however, was the stated policy that the Bureau of Aeronautics controlled and prepared descriptive and performance specifications of aircraft electronic equiment, in order to insure that the equipment would perform satisfactorily as an integral part of the airplane and fulfill its special functions.[18]

On 7 December 1942 Hall was detached for sea duty. He was relieved by Comdr. Frank Akers, USN. Under Akers' direction there was a continued building up of the staff and its translation into a smooth-working organization, the refining of procedures and methods, and the shift of emphasis from individual material developments to the engineering of complete electronic systems for aircraft. The initial step taken in this direction was the establishment of the Systems Planning Board on 11 December 1942 to consider and recommend on problems of overall electronic equipage of naval aircraft. A complete reorganization of the section to implement operation along these lines became effective 22 March 1943. For this functional organization there were two groups, one of which comprised the technical subsections who were responsible for project engineering of individual items of electrical and electronic equipment, and the second comprising the aircraft installation desks, the engineers of each being responsible for manufacturing liaison with

[18] Letter, dated 4 Dec. 1942, Bureau of Ships, files F42-1 (900).

aircraft manufacturers on problems relating to the actual installation of this equipment in aircraft of their specifically assigned type. The Technical Subsections were Radio Communications, Accessories, Navigation, and Advanced Communication Design, Radar, Radio Control, and Electrical.[19]

As a further implementation to the Systems Planning Board, provision was made for the establishment of "Engineering Type Groups" for each new airplane, comprised of responsible engineers from each technical subsection whose equipment was involved, with the Aircraft Installations Subsection member cognizant of that airplane as chairman. These engineering type groups were charged with the responsibility of producing the necessary detailed information leading to proper installation of the equipment in aircraft.

On 23 July 1943, in accordance with the general reorganization of the Bureau and the establishment of engineering as a division, the Radio and Electrical Section became a branch and its former subsections were redesignated as sections. In line with minor reorganizations effected at this time, the Technical Assistant for Material became the Assistant for Electronics Material and assumed direction of the Material Section and the Electronic Coordination Section, while the Technical Assistant for Installation Coordination became the Assistant for Installations and assumed direction over the Aircraft Type Installation sections.[20]

In February 1944 the Countermeasures Section was formed from a subsection of the Radar Section because of increased operational importance of countermeasures equipment and because countermeasures work applied not only to radar but to radio and IFF as well.[21]

One of the chief duties of the Systems Planning Board was the specifying of equipage for the types of naval aircraft. It soon became apparent that the directives in the form of the minutes of the Board were unwieldy and confusing. The Board established, in May 1943, the system of listing equipage recommended by the Radio and Electrical Section in the form of a numbered directive which was submitted to the class desk, military requirements and to the Office of the Chief of Naval Operations for approval. After approval the directive was issued to all interested activities for action and initiation of necessary procurement. At this time the "Radio and Electrical Assembly Sheet" was established. In effect this was a specification for procurement purposes. It listed all components required for a specific installation of a given type of equipment. Another procedure established at this time was the provision for stock pool procurement. It had been the practice to procure quantities of new equipment for the purpose of initiating manufacture so as to assure that quantity production would be available to meet estimated aircraft equipage needs without actual allocation to specific aircraft. The stock pool was set up as a standard method of making such procurement in the future.[22]

While the preparation of a joint Bureau of Aeronautics and Bureau of Ships letter in December 1942 clarified the cognizance of the two bureaus with respect to aircraft electronic equipment, the growing importance of airborne fire control radar equipment and other airborne electronic equipment related to ordnance material brought up questions of respective cognizance of the Bureau of Ordnance and the Bureau of Aeronautics. In November 1942, the Bureau of Ordnance had asked for a review of cognizance equipment and the Bureau of Aeronautics proposed on the 18th of November 1942 that a group from the Bureau of Ordnance, the Bureau of Ships, and the Bureau of Aeronautics review the entire subject of airborne electronic ordnance devices.[23] The Bureau of Ordnance and the

[19] Letter, dated 1 Nov. 1944, Bureau of Aeronautics file, Aer–3–310–IHG.

[20] Ibid.

[21] Ibid.

[22] Ibid.

[23] Letter, dated 18 Nov. 1942, Bureau of Aeronautics file, Aer–E–314–JTK, F42–8 (1).

Bureau of Ships concurred with this proposal and Comdr. H. C. Owen, USN, Bureau of Ships, Comdr. D. P. Tucker, USN, Bureau of Ordnance, and Lt. Comdr. L. V. Berkner, USNR, Bureau of Aeronautics, met to draw up a proposed agreement defining the responsibilities of the respective Bureaus. They recommended definition of responsibilities in a letter dated 14 April 1943.[24] The Assistant Chief of the Bureau of Aeronautics directed the Radio and Electrical Section to incorporate these agreement into the previous joint Bureau of Aeronautics and the Bureau of Ships letter. No immediate action was taken, however, because the Bureau of Aeronautics and the Bureau of Ships negotiations on a change of cognizance had again been reopened. A Bureau of Aeronautics and a Bureau of Ordnance letter was not prepared because the Chief of the Bureau of Ordnance failed to approve the recommendations.

Delays late in 1942 in the delivery of essential airborne radio and radar equipment needed by the Fleet had been called to the attention of the Assistant Secretary of the Navy for Air who became seriously concerned and asked for corrective measures. Captain Akers stated that the problem of divided cognizance was to a large measure responsible, and stated the existing problems in writing in a memorandum of 6 February 1943, pointing out the previous history of difficulties which had resulted from divided cognizance and the lack of contact between the Bureau of Aeronautics and the manufacturer.[25] The Assistant Secretary of the Navy (air) appointed Mr. Fred Riebel to look into the situation both in the Bureau of Aeronautics and the Bureau of Ships. He proposed no sweeping changes but did cause some reorganization of the Bureau of Ships Radio Division.

About this same time management engineers were about to begin a survey of the Bureau of Aeronautics. After discussions with Akers, they decided to survey the situation in the Bureau of Ships. After considerable study they recommended the transfer of cognizance over aircraft electronic material to the Bureau of Aeronautics. Captain J. B. Dow, USN, Head of the Bureau of Ships Radio Division was also convinced that the change would be the best solution. A Bureau of Ships letter was prepared proposing this change but it was not effected. Vice Adm. S. M. Robinson, USN, of the Office of Procurement and Material became interested and indicated his opposition. Rear Adms. E. M. Pace and E. W. Mills, USN, were directed by the Chiefs of the Bureau of Aeronautics and the Bureau of Ships respectively to investigate all steps short of an actual transfer of cognizance that might be taken to improve the situation. Akers' memo of 6 February and the proposed letter defining the cognizance of the Bureau of Aeronautics, Bureau of Ordnance, and the Bureau of Ships were forwarded to them for consideration. On 8 June 1943 they recommended that cognizance not be transferred but that representatives of the two Bureaus reach agreement on means of improving the coordination of electronics administration and production under the existing divided cognizance. It was further recommended that the personnel of the two Bureaus should have it instilled in their minds that it was a joint effort and further discussions concerning change in cognizance should be discouraged. These recommendations were approved by the Assistant Secretary of the Navy for Air on 16 June 1943. Subsequent action resulted in a revised draft of the joint cognizance letter which gave both bureaus joint responsibility for all phases of development and procurement. This letter was approved by the Acting Secretary of the Navy in October 1943.

With this question of cognizance settled, it was possible to hold further conferences to consider cognizance of the Bureau of Ordnance. A Bureau of Ordnance-Bureau of Ships joint letter covering fire control radar was prepared 27 December 1943, and

[24] Letter, dated 14 Apr. 1943, Bureau of Aeronautics file, Aer–E–31T–CG, F42–5, F42–8 (1).

[25] Letter, dated 6 Feb. 1943, Bureau of Aeronautics, files, Aer–E–31HES, F42–1, F42–5.

on 18 February, 1944 a Bureau of Aeronautics - Bureau of Ordnance - Bureau of Ships letter was approved. Following approval of this letter specific action on individual airborne ordnance radar equipment under development was decided upon in light of directives of the joint letter.[26]

The desirability of clarifying and consolidating all the existing cognizance letters was brought out by a Director, Naval Communications letter[27] of 11 May 1944, which pointed out the responsibilities of the Director, Naval Communications insofar as electronic equipment was concerned. This letter directed that new joint letters be prepared which conformed to the policy that the Director of Naval Communications was responsible for the assignment of frequencies, the military characteristics and allowances of all electronic equipment (except fire control), the IFF policy, countermeasure doctrines and policies, integration of the material training program for electronics personnel, and the coordination of fire control radar, countermeasures and antijamming. Rear Adms. W. A. Kitts and Joseph R. Redman, USN, and Capts. Dow and Akers, were designated to draw up a new letter. On 11 July a letter was prepared by the Office of the Chief of Naval Operations to the Chiefs of the three Bureaus covering cognizance of radio and radar equipment. This letter gives the Bureau of Aeronautics primary cognizance of all airborne radio and radar equipment, and assigns the Bureau of Ships the responsibility for design and procurement of such equipment. It requires the Bureau of Ships to follow the recommendations of the project groups of the Bureau of Aeronautics, the Bureau of Ordnance, and the Bureau of Ships in developing airborne fire control radar. Although not promulgated, it was accepted as a modus operandi, and was followed during the remainder of the war.

[26] Letter, dated 18 Feb. 1944, Bureau of Aeronautics, file Aer–E–31–LVB, F42–5, F42–1.

[27] Letter, dated 11 May 1944, Director Naval Communication, file Op. 20–E/AB (1132120).

The Radio and Electrical Section had early enunciated the policy that as much as possible of the complete electrical and electronic installation should be made by the airplane contractor. For confidential equipment, however, no arrangements had been made to permit handling by the contractor and such equipment was actually installed by naval activities after provisions had been made in the airplane for mounting and connections. It was realized that such a policy tended to militate against the best possible installation. The airplane contractor could not consider the confidential equipment as an integral part of the airplane and make his design accordingly and considered the radar equipment merely an attachment which he knew nothing about and had no concern with. In order to correct this situation an extensive study of the subject was undertaken in early 1944. A determination was made as to when aircraft contractors would be able to undertake installation of confidential equipment.

Concurrently, formal approval of this policy was sought and obtained from the Chief of Naval Operations.[28] To implement this, more detailed training of contractor personnel was begun in a course convened at the Massachusetts Institute of Technology, on 21 August 1944. Following the fundamental principle that the greatest value accrues from incorporation of the many electronic devices as a coordinated system in the basic airplane design, the Radio and Electrical Branch initiated the first contract change to provide for contractor installation on an experimental design, the XTSF. The change was approved on 10 Otcober 1944.

ELECTRONICS ORGANIZATION OF THE BUREAU OF ORDNANCE

The Bureau of Ordnance, established in 1842 before the time when gun mounts

[28] Letter, dated 6 July 1944, Director Naval Communications file Op–20–Ells (0220720).

entered into ships structural design to any great extent, was one of the longest lived of the Navy's material Bureaus.[29] It survived the reorganization of 1940 when the Bureaus of Engineering and Construction and Repair were consolidated into the Bureau of Ships. In the field of ordnance it became supreme and dictated ship construction to meet the need for guns of ever-increasing calibre.

The early interests of this Bureau in electronics were in the development of the radio-controlled torpedo and radio-controlled flying missile, but in both of these the engineering Bureau was responsible for the radio installations. Neither of these projects reached the production stage prior to the end of World War II and cognizance was of little consequence.

Radar was first adapted to fire-control purposes under the aegis of the Bureau of Ships as the agency responsible for electronics. In 1940 the Bell Telephone Laboratories developed a fire control radar working in a frequency band which made possible the extremely narrow beam required for fire-control purposes. The Bureau of Ships purchased 10 of these sets, originally designated CXAS, later changed to FA and finally redesignated Radar Mark I. This equipment fell short of expectations and it was abandoned in favor of Radar Mark III.[30]

As the importance of radar to the fire-control problem became apparent, the matter of cognizance became extremely important. The Bureau of Ordnance was faced with the necessity of repackaging and redesigning equipment procured by the Bureau of Engineering in order to integrate it with existing fire-control installations. Bureau of Ships officers were less familiar with fire-control problems and less impressed with the necessity of rapid improvement of fire-control radar. Although close liaison was maintained the dual cognizance was annoying and hampering.[31]

In the summer of 1941 an informal agreement was reached between the two Bureaus which gave Ordnance cognizance over all aspects of fire-control radar except the electronic features. This agreement was formalized in October of the same year and was immediately followed by a parallel agreement with the Bureau of Aeronautics. By these agreements Ordnance exercised control over military requirements, mechanical design, packaging, production, and installation in ordnance locations in ships and aircraft. In carrying out its new responsibilities the Bureau made little change in its basic organization. A Fire Control Radar Section, successively headed by Capts. M. E. Murphy and D. P. Tucker, USN, was added to the Research and Development Division. The negotiation of contracts for procurement of fire-control radar was handled by the Production Division. In early 1942 all existing fire-control contracts were transferred from the Bureau of Ships and subsequent ones were placed by the Bureau of Ordnance. This organization, with considerable personnel expansion, continued throughout the war.[32]

The Bureau of Ordnance exercised a strong control over fire-control radar design by the Bureau of Ships but this was considered as outside interference by the personnel of the latter activity. In December 1943 the cognizance problems between the two Bureaus was further reduced, by increasing Ordnance's production responsibility, but much was left to be desired. Moreover relations with the Bureau of Aeronautics were not completely satisfactory because the development of instruments satisfactory to both Bureaus was extremely difficult.[33]

The positions of the Bureaus of Ordnance and Aeronautics and their relationships with the Bureau of Ships in the radar field were identical with the exception that

[29] In 1960 the Bureaus of Ordnance and Aeronautics were consolidated in a Bureau of Weapons.

[30] Buford Rowland and Williams Boyd, "U.S. Navy Bureau of Ordnance in World War II;" Washington, Government Printing Office, 1953, pp. 414–415.

[31] Ibid., p. 415.

[32] Ibid., pp. 415–416.

[33] Ibid.

Ordnance was able to make its own contracts and select its contractors without interference. The "Administrative History of the Bureau of Ships During World War II" (p. 248) justifies the difference in the agreements with the two bureaus by the following statement:

> The transfer of fire control procurement to the Bureau of Ordnance . . . stemmed primarily from the fact that fire control procurement amounted to only five or six million dollars monthly and was concentrated almost entirely in our company, Western Electric. By contrast, however, the Bureau of Aeronautics procurements constituted a very large volume—even larger than that of the Bureau of Ships—and were scattered among many of the same companies furnishing Bureau of Ships requirements. To allow the Bureau of Aeronautics to procure independently would have split the Navy contracting into competing and administratively independent camps . . . .

In the proximity fuze program the Bureau of Ordnance had no cognizance problem. Despite the fact that its actuating device is in all respects a miniature radar it is so intimately integral with the remainder of the fuze train that to have considered it a component under the cognizance of the Bureau of Ships would have been ridiculous. Moreover, it was developed under the sponsorship of the Bureau of Ordnance, by contract with commercial research activities with whom the Bureau of Ships was never involved.

EPILOG

In retrospect the divided cognizance did not greatly hamper the war effort. Equipments were designed, developed, produced, and distributed satisfactorily. Perhaps this could have been accomplished with less administrative effort had there been undivided cognizance over components of weapons systems. However, radar, which was the main bone of contention, developed quite rapidly, and before the problem had become evident the war was upon us. During war rapid expansion of existing organization presents serious problems and basic changes and realinements only serve to compound them. In the years that followed the war, the problems of divided cognizance were slowly resolved and from a consolidation of Ordnance and Aeronautics there was established a Bureau of Weapons, which has complete control over the components of all weapons systems.

CHAPTER XXXVII

Procurement and Distribution of Electronic Material

GENERAL CONTRACT PROCEDURES

Until June 1940 the Navy's contract procedures were archaic. Governed by Revised Statute 3709, enacted in 1861, which required advertisement of proposals, competitive biddings, and the awards of contracts to the lowest bidders offering materials meeting the specifications, it was a slow and cumbersome process. During the years following the enactment of this statute contract requirements became more restrictive by the addition of numerous administrative rulings and congressional restrictions in the annual appropriations bills. An act of Congress in 1911 permitted progress payments on contracts but prohibited advances.

Under the established procedure two contract methods were open to the material bureaus: one in which the bureaus prepared the contract and either sent it to the Secretary of the Navy or the Chief of the Bureau for signature and then executed it; and the other in which requisition was made upon the Bureau of Supplies and Accounts which then prepared and executed the contract. The former type was normally used to obtain technical apparatus which required contract surveillance by personnel with knowledge of the apparatus required. Items of standard equipment were normally procured by requisitions on the Bureau of Supplies and Accounts.

During World War I it became necessary to resort to a "cost-plus-percentage" type of contract because of spiraling prices which made it impossible for contractors to determine costs. Following the termination of the war this means of contract procurement was prohibited.

These contract procedures had the virtue of simplicity and were easy to administrate. Weaknesses were hidden or overlooked because speed in procurement was not a vital consideration in most cases and, in the few where it was, the cumbersome methods could be accelerated as long as procurement remained at a low level.

In addition to the unidealistic contract procedures, Congress customarily embodied a restriction in the annual appropriation bills designed to require material to be produced in navy yards or arsenals when this could be done "in the time required, at no excessive cost." However, this had but little effect upon the procurement of electronic equipment, since the Navy did not possess all the necessary patents and could not obtain license to use the essential ones that would permit the manufacture of equipment which would meet the specifications.

With the gradual expansion of the Navy which began in 1933, the weaknesses of the contract procedure became evident. As the buildup accelerated it became ever more apparent that the legal restrictions necessarily had to be less stringent and that procedures must be streamlined. In 1939 all material bureaus of the Navy united in a concerted attack against the contract restrictions. The appropriations of that year carried the usual customary restrictions but permitted the Secretary of the Navy to waive them when required for national defense. In January 1940 the Secretary removed all administrative restrictions which had been placed by his Office during the preceding decades.

In June 1940 Congress awakened to our need for total preparedness and enacted Public Law 671 which eliminated peacetime restrictions and revolutionized traditional procedure for procurement of military equipment. This act permitted the Secretary of the Navy to authorize, when necessary, procurement through negotiated contracts without advertisement or competitive bidding and permitted the use of "cost-plus-fixed fee" contracts. Another important provision of the act, which was to prove extremely valuable in the years to follow, permitted advance payments to contractors up to 30 percent of the contract price.

With the enactment of this law three additional methods of contract procurement became available to the material bureaus: contracts negotiated under Public Law 671; contracts negotiated by representatives of a material bureau assisted by representatives of the Bureau of Supplies and Accounts and then executed by the latter Bureau in response to requisition; and contracts by which a material bureau could finance critical industrial expansion. Additionally, the use of the letter of intent which authorized a manufacturer to begin work with assurance that he would be reimbursed for his expenses up to a fixed amount in the event a contract did not develop.

After the attack on Pearl Harbor, time, rather than economy, became the controlling factor in military procurement. On 27 December 1941, the President, exercising the power conferred upon him by the First Wars Powers Act of 8 December 1941, granted the military departments general authority to contract through negotiation. On 28 December 1941, the Secretary of the Navy directed that supply and contract facilities contracts in excess of $200,000 would only be executed with the authorization of his Office. Contracts involving expenditures in excess of $500,000 required the additional clearance of the War Production Board. To assist the Secretary's Office in coordinating the business activities of the Navy, the Office of Procurement and Material was established in January 1942 and this Office was authorized to act for the War Production Board. In early 1942 the War Production Board issued a directive which, to all practical intent, made contract by negotiation mandatory. A few months later this was amended by directing that primary emphasis be placed upon "deliveries or performance at the times required by the war program."

Despite the liberalization of the contract procedures, procurement by the material bureaus was being slowed by the lack of administrative flexibility and lack of technical knowledge within the Bureau of Supplies and Accounts. To bring the situation into the open, the Chief of the Office of Procurement and Material, in July 1942, queried the material bureaus as to the advisability of centralizing all procurement in the Bureau of Supplies and Accounts. The technical bureaus united in opposition to this proposal and were successful in their efforts. On 13 December 1942, the Secretary of the Navy directed the material bureaus to handle their own contracts for research, development, and production of the technical items under each bureau's cognizance and to procure standard stock items of a nontechnical nature through the Bureau of Supplies and Accounts. To further facilitate procurement each bureau was directed to establish a legal office headed by an appointee of the Under Secretary of the Navy who was responsible for insuring that contracts were legally prepared.

BUREAU OF SHIPS ELECTRONIC EQUIPMENT PROCUREMENT [1]

The Bureau of Ships procured electronic

[1] The information contained under this sub-heading was obtained from "An Administrative History of the Bureau of Ships During World War II," first draft narrative prepared by the Historical Section, Bureau of Ships; unpublished and undated, pp. 283– 294.

equipment for the entire Navy, including the Marine Corps, excepting that required by the Bureau of Ordnance. Additionally, it made procurements for the Maritime Commission and the Lend-Lease Administration and for some of the Army's requirements.

In the early days of the war, procurement was handicapped by four factors: No radar designs suitable for production existed in 1939 nor were any allowances established for this equipment; the lack of a capable organization for negotiating, determining requirements, expediting, and progressing; lack of experience on which to negotiate prices sufficiently high to serve as an inducement to manufacturers; and lack of sufficient number of firms with electronic production capabilities or facilities.

An adequate means of determining electronic requirements had not been developed by 1942. A requirements and allowances program had been projected, but this required starting with plans and procedures, data on sizes, voltages, power supplies, mast heights, strengths, and freedom from obstructions and other pertinent ships' construction data affecting installations. All these factors were important for all electronics installations and were vital in the case of radar. Beginning in March 1942, a thorough study of the physical and electrical characteristics of each ship type was made. Following the completion of this during the summer of that year recommendations were made to the Chief of Naval Operations for radar installations by ship's type.

As mentioned earlier, legally, the function of selecting contractors, negotiating prices, and awarding contracts was the province of the Bureau of Supplies and Accounts. In the field of electronic equipment, that Bureau had for many years been dependent upon the Radio and Sound Division for the required technical assistance. With accelerated procurement it became necessary for the Bureau of Ships to assume most of this function with the Bureau of Supply and Accounts merely approving contractural actions.

The authority for initiating requests for electronic equipment procurement came from the Chief of Naval Operations by the establishment of ship and shore station allowances or by request for specific equipments from the Bureau of Aeronautics based upon aircraft allowances which were also established by the Chief of Naval Operations, from requisitions of the Marine Corps, Army, Maritime Commission, and the Lend-Lease Administration, plus an estimated requirement for battle damage.

Until shortly after the attack on Pearl Harbor each individual section of the Radio Branch negotiated its own procurement. After the establishment of the Office of Procurement and Material they were assisted by negotiators from the Procurement Division and contracts exceeding $200,000 were reviewed and approved by the Contract Clearance Division of that activity. It quickly became obvious that too many individuals, lacking firm requirements guidance, were initiating procurement. In late spring 1942 procurement was centered in one Procurement Section.

Because of lack of adequate pricing experience, compounded by rapid changes in specifications, which necessitated keeping design fluid, and the urgent requirements for electronics equipment, 70 percent of the negotiations prior to July 1944 began with issuance of letter of intent or by contracts specifying maximum cost with later downward revisions. Cost-plus-fixed-fee contracts were seldom used as manufacturers opposed them and the Navy's Cost Inspection Service was not adequate to cope with a large volume of this type.

The Office of Procurement and Material became increasingly critical of the Bureau's use of the letter of intent. In mid-1944 this culminated in an investigation of its use of this means of starting electronic production. As a result, in July 1944, electronic procurement was transferred from the Electronics Division to a Contract Division, established under a civilian head provided by the Office of Procurement and Material. Following this, a Contract Planning Section was established in the Equipment Branch of the Electronics Division. This Section aided in preparing requests for procurement, contract modifications, or change authorizations. It insured that the technical problems of production were legally covered, aided in the selection of contractors, insured that contract specifications agreed with what the contractor promised, and protected the Government's patent position.

The Contract Division thus received papers nominating contractors, specifications, quantities of material required, exceptions filed by contractors to the specifications, the financial appropriation to which the contract was chargeable, and information relative to the furnishing of material by the Government. It was not usually possible to provide the contract negotiators with all the required information. This resulted in appeals to the Contract Planning Section for additional technical assistance and brought about close liaison and considerable joint action.

Although considerable electronic equipment was purchased from small manufacturers, the major portion was provided by the following:

Western Electric Co.;
Westinghouse Electric & Manufacturing Co.;
Radio Corp. of America;
Philco Electric Corp.;
Collins Radio Co.;
Submarine Radio Co.;
Hazeltine Service Corp.;
Sperry Gyroscope Co.;
Stromberg Carlson Co.;
Federal Telephone & Radio Co.;
Aircraft Radio Corp.; and the
National Electric Supply Co.

The magnitude of the procurement of electronics equipment is best understood in terms of dollars. Between 1 November 1942 and 1 September 1945, contracts had been awarded for equipment in the amount of $4,009 million, of which $2,538,800,000 in deliveries were made. In July 1944, following the Normandy invasions, contracts began to be canceled for excess and undelivered obsolescent equipments. These cancellations totaled $1,058,400 by 1 September 1944, leaving an undelivered balance of $400,800,000. Most of this amount was not recoverable because of obligations incurred by contractors for material, components, completed but undelivered equipments, plant facilities, and services.

This appears a huge sum, but it must be remembered that the military services were, at the sudden termination of hostilities, preparing an all-out invasion of Japan and that this equipment would have been required had this taken place. War is expensive and wasteful, but poverty is far more acceptable than slavery.

BUREAU OF ORDNANCE ELECTRONIC EQUIPMENT PROCUREMENT [2]

The electronic equipment requirements of the Bureau of Ordnance were primarily in two separate and distinct fields; fire-control radars and proximity fuzes. Early fire-control radar equipment was obtained under Bureau of Ships contracts. The Bureau of Ordnance assumed the responsibility for research, development, and procurement of fire-control radar equipment after mid-1941. Since this type of radar required the use of much higher frequencies to provide the narrow beam required for fire-control purposes, additional research was required. This was carried out under National Defense Research Committee and Office of Scientific Research and Development contracts with the Radiation Laboratory, established at the Massachusetts Institute of Technology. The costs of the development of the equipment to meet naval fire-control problems was borne by the Bureau of Ordnance. Approximately $14 million was expended for this purpose during the war years. The equipment produced from this development totalled $400 million during the same period. Most of the development and pro-

[2] Buford and Rowland, op. cit., pp. 408–432; 271–286; 448–460.

curement was centered in the Bell Telephone Laboratories and the Western Electric Co.

The development of the proximity fuze was sponsored by the Bureau of Ordnance. In August 1940 it made this project top priority on which National Defense Research Council work was desired. In complying with this priority request, a new section which conducted its research at the Carnegie Institution was created under the Council. In November 1941, the Bureau contracted with the Crosley Corp. to assist in this research by provision of realistic engineering design. Rapid development was achieved, and by the end of 1941 numerous companies were conducting research under National Defense Research Council or Bureau of Ordnance Contracts. In March 1942 the responsibility for this project was transferred to the Office of Scientific Research and Development; it placed the administration of the project with John Hopkins University, which established the Applied Physics Laboratory at Silver Spring, Md., for this purpose.

In August 1942 successful tests of fuzes developed under this project permitted crystallization of specifications of the fuze for combat purposes and in November 1942 the first produced from these were rushed to the Pacific theatre of operations and were introduced upon the enemy on 5 January 1943.

Although placed in quantity production, the design of the fuze remained fluid because rapid developments brought forth numerous improvements and miniaturization. At the end of 1944, with design more permanent, the cognizance of the project was released by the Office of Scientific Research and Development and taken over by the Bureau of Ordnance which retained the Johns Hopkins University's administration.

Over $50 million was obligated for the proximity fuze development and facilities before a single one had been service-tested The procurement structure was a complicated one. The Chief of the Bureau of Ordnance made every possible effort to free the program by authorizing the elimination of any and all factors that threatened to slow production, but the necessity for secrecy, the small number of capable contractors, and the requirement for miniaturized electronic components, which were slow and tedious of manufacture, offset much that was done to hasten the program. By October 1942 an average of 500 fuzes per day were being delivered. Demand by all Allied services required a set-up in production and the establishment of additional facilities under facilities contracts. By the end of 1943 almost 2 million had been delivered. A year later they were being turned out in excess of 40,000 a day. The value of procurement contracts climbed from $60 million in 1942 to $200 million in 1943. The following year $300 million was obligated and for the final year of the war, $50 million. Deliveries rose more rapidly than dollar expenditures because the cost of the fuze dropped from $732 in 1942 to $18 in 1944.

Numerous firms were utilized to manufacture components of the proximity fuze. Several companies made attempts to mass-produce the minature electronic tube, but only Sylvania Electric Products, Inc., proved capable of combining quality with the mass production required. The special batteries, energized upon firing, were supplied by the National Carbon Co. Assembly was concentrated in five companies: the Crosley Corp.; the Radio Corp. of America; the Eastman Kodak Co.; Sylvania Electric Products, Inc.; and, the McQuay-Norris Co. All of these firms and their subcontractors, working under secrecy, not entitled to fly the incentive Army-Navy E pennant nor to provide their workers with the coveted lapel buttons to indicate their share in the war effort, rendered services to their country far in excess of that which would normally be expected even in time of grave national emergency.

Unlike the other material bureaus, the Bureau of Ordnance centered all its procurement with one unit, the Procurement Branch of the Production Division. In initiating a procurement contract the responsible technical section prepared an analysis of its procurement of a specific end item. This indicated total requirement, amounts already under contract, and current and prospective rates of delivery. The technical section also nominated the contractor with due regard to the War Production Board directive, available labor supply and the productive facilities capable of utilization. The analysis and contractor nomination were forwarded to the Plant Equipment Section for certification that the procontractor possessed the facilities to complete the contract within the specified time. If this was obtained the proposed contract passed on to the Production Planning Section for further certification that the procurement was in accord with Bureau of Ordnance policies. Following this, a Controlled Materials Plan allotment number was assigned and the proposed contract was forwarded to the Procurement Branch. The Head of this Branch determined whether the procurement could be placed in a naval ordnance plant or awarded a private contractor. If decision was made to use private plants he then obtained clearances from other Navy agencies. Following this, the proposal was forwarded the legal office for preparation of a formal contract.

The letter of intent was used when the urgency for the material necessitated the inauguration production. In no case were they allowed to remain in force for over 60 days without the approval of the Office of Procurement and Material. The letter of intent was usually followed by a fixed-price contract and where this was impracticable by cost-plus-fixed-fee contract.

EXPEDITING THE PRODUCTION OF ELECTRONIC EQUIPMENT

For the greater part of the war expediting the production of electronic equipment was a joint military effort. In the latter part of 1941 the Army Signal Corps established an expediting group to speed up production and to reduce contractor delinquencies. In July 1942, it became evident that the Navy's radar production program was falling behind. Each procurement section was performing its own expediting service, with the result that several members of the Radio and Sound Division might be competing with each other for the services of the same firm. At this time, a Progress Section was established under the Production and Procurement Branch which was assigned the expediting function. Plant liaison officers were assigned who, in turn, were reassigned to the above-mentioned Army erpediting group which was, in July 1942, renamed the Army-Navy Communications Production Expediting Agency, remaining under Army administration. In October of the same year, this Agency was reorganized and became a separate activity, the Army-Navy Electronic Production Agency (ANEPA), under a civilian Director. The head of the Radio and Sound Division, Bureau of Ships, and the Chief of the Signal Supply Services, Signal Corps, were made Associate Directors. At this time the activity was composed of 373 persons, mostly employed by the Army. A year later its staff had expanded to over 1,000, of whom 350 were expediters in the field engaged in aiding 5,000 different manufactures.

The ANEPA was responsible for speeding production of radio, radar, sonar, telephone, telegraph, and all other electronic equipment, being produced for the military departments. Its functions were to insure the delivery of piece parts and materials to contractors as necessary to assist them in meeting delivery times; to obtain higher priorities from the Joint Communications Board for urgent end products to enable manufacturers to concentrate on their productions; to obtain draft deferments of key production personnel; to obtain necessary financial assistance and additional facilities as necessary; to insure that contractors complied with change orders and stabilized design as quickly as possible; to insure the production of equipment in the order of its importance; and to provide Government agencies information concerning the reliability and capabilities of contractors. The Agency's policy was to avoid interfering with a manufacturer's operations, and to take action only after one had exhausted his own resources. Many of these functions essentially belonged to the War Production Board, but that agency tacitly left them to the ANEPA.

To assist the ANEPA and to provide the information essential for it to meet Navy delivery requirements a series of monthly production reports was initiated in late 1942 which listed pertinent data concerning all Navy contracts. The first of these brought out the fact that 93 percent of the dollar value of the Navy's electronic contracts were concentrated in the largest 14 of 44 contracts. This information aided in directing distribution of critical components and raw materials.

The ANEPA performed its functions with less delay, less expense, and fewer personnel than would have been required had both services retained separate agencies. This notwithstanding, despite Navy pleas, it was disestablished in mid-1944 in the belief that the work could be undertaken by service procuring agencies and the War Production Board. This left the Navy in an extremely poor situation in the field and resulted in the functions necessarily being assumed by overburdened personnel of the Navy Inspection Service.

BUREAU OF SHIPS DISTRIBUTION OF ELECTRONIC EQUIPMENT [3]

Prior to the war, electronics equipments were purchased for specific ships. By May 1942, equipments were being delivered in volume from contracts awarded prior to and after the attack on Pearl Harbor. They continued to be distributed directly from factories to various navy yards or shipbuilders earmarked for a particular ship. This often resulted in equipment, which was badly needed elsewhere, remaining in storage for months awaiting ship availability or completion. In some cases equipment remained stored for vessels which had been sunk.

By late 1942 ships were being launched at such a rate that it had become impossible to tie down completion dates and to foresee exact electronic installation dates or to keep specific equipments tied to specific ships. To insure availability of equipments when required, the old method was abandoned and pools of electronic equipments were created at all navy yards requiring this material. From these pools it was allocated by the yards' radio material officers under the directions of yards' industrial managers.

As originally established, there was no tie-in of issues of equipage with combat requirements. This often resulted in a claimant with an established large requirement, not connected with combatant vessels, exhausting the supply of any particular equipment in short supply. This situation was eliminated, in the summer of 1943, when the Chief of Naval Operations set up the following four precedence categories to control pool issues:

1. New construction, controlled by the Bureau of Ships;
2. Maintenance of ships, controlled by forces afloat;
3. Shore stations, controlled by the Bureau of Ships; and
4. Advance bases, controlled jointly by the Commanders in Chief Atlantic and Pacific Fleets.

Later, a fifth category was established to take care of equipment removed from ships and shore stations. This was controlled by the Bureau of Ships for reassignment to the above categories.

To assist in administering the category system an Assignment Section was organized in the Radio and Sound Division. This Section used the directives of the Chief of Naval Operations as a guide in assigning the total estimated production of each type

[3] "An Administrate History of the Bureau of Ships During World War I," op. cit., pp. 311–315.

of electronic equipment to the several categories from which the controlling activities then distributed equipment to its own claimants in accord with the particular requirements.

By July 1944, there was enough equipment in stockpile to meet practically all requirements. This eliminated the necessity of rigid control of issues and the category system was abandoned. From that time on, equipment was shipped to general stock for issue. In the few cases of apparatus in short supply, the Radio and Sound Division determined distribution and in extreme cases asked the Office of Chief of Naval Operations to render the decision.

The establishment of the pool system made it desirable to provide each pool with a supply officer for radio who possessed adequate knowledge of the complexities of electronics equipments and of the thousands of different types of spare parts and components.

The Distribution Liaison Section provided shipping instructions by writing manufacturers letters which were sent to the Bureau of Supplies and Accounts for signature. Each of these contained a summary of the current status of shipment, including quantity undelivered under the contract. Copies of these were provided each consignee and the appropriate inspectors of naval material. This Section also acted as a clearinghouse and central point of contact between the Bureau and contractors, consignees, and naval inspectors whenever two or more activities such as Army, Marine Corps, Maritime Commission, and Lend-Lease Administration were claimants of the same equipment.

Shipments were scheduled in accordance with requirements determined by the progress of new construction, maintenance needs as reported monthly by fleet services forces, and by the requirement of the above-mentioned outside claimants. The actual mode of transport, air, rail, and ship, was determined by the Transportation Section of the Bureau of Supplies and Accounts to meet deadline dates provided by the Bureau or the service forces.

BUREAU OF AERONAUTICS DISTRIBUTION OF ELECTRONIC EQUIPMENT

Prior to the war, all electronic equipment procured for the Bureau of Aeronautics was shipped from the manufacturer to the Naval Aircraft Factory, Philadelphia, Pa., for acceptance tests and installation in newly acquired aircraft or for storage. Prewar expansion of naval aviation rendered this procedure unsatisfactory. In mid-1944 the Bureau of Aeronautics Circular Letter 38–41 established the policy of having aircraft contractors install all unclassified electronic equipment. Thereafter, such equipment was shipped from the manufacturers' plants to those of the aircraft contractors.

Electronic repair facilities were established at the naval air stations at Norfolk, Philadelphia, Quonset Point, San Diego, Alameda, Seattle, Coco Solo, and Pearl Harbor. At these facilities pools of aircraft radio equipment were established to provide replacements of obsolescent or damaged equipment in existent aircraft. Equipment was shipped direct to these facilities from electronic manufacturers' plants.

Beginning in April 1942 all but the classified components of radar equipment were shipped to aircraft contractors for installation during construction. Classified components were shipped to the aircraft repair facilities pools for installation by the faciities or by squadron personnel. This procedure was continued until July 1944 when approved aircraft contractors were directed to incorporate complete aircraft electronic system during aircraft construction. Thereafter, classified components were delivered to them under safe handling.

Shipping was handled by the Bureau of Supplies and Accounts, using whatever mode of transportation required to meet established deadlines.

BUREAU OF ORDNANCE DISTRIBUTION OF ELECTRONIC EQUIPMENT

The distribution problem of the Bureau of Ordnance was far less complicated than those of the other two material bureaus. Proximity fuzes were normally handled in the same manner as other ammunition through ammunition depots to service forces ammunition ships for distribution to fleet units to replace expended fuzes.

The Bureau made no attempt to establish separate fire-control radar maintenance units, but depended solely on the existing organizations at navy yards and advance bases, and had equipment shipped from the Western Electric Co. plants to navy yards and service forces pools as anticipated by the requirement of installation in ships under construction or for fitting in fleet vessels.

CHAPTER XXXVIII

Radar

PROLOG [1]

It is doubtful that the development of any electronic system is as confused by as many unsubstantiated claims and conflicting and confusing reports as that of radar. Volumes have been written, some fanciful, some more or less factual, yet colored by pride of discovery or development. Some, written at the instigation of a company or laboratory which had a part in the development, tend to overemphasize particular contributions. In the U.S. Navy the story of its development is further complicated by the divided responsibilities which existed within the Navy Department. The Chief of Naval Operations was charged with providing the military characteristics of equipment. The Chief of the Bureau of Engineering was legally responsible for the development, procurement, and maintenance of electronic equipment. The Chief of the Bureau of Construction and Repair entered the picture to the extent that he was responsible for ship stability. The Chief of the Bureau of Ordnance was responsible for fire-control applications and configurations of equipments for installation in fire control spaces in ships and aircraft. The Chief of the Bureau of Aeronautics was responsible for air search applications and the configuration of installations in aircraft. The Chief of the Bureau of Supplies and Accounts was responsible for contractural procedures. A further complication was the attempt of the Joint Communications Board to cope with the chaotic conditions which existed in the electronics industry caused by military requirements far exceeding manufacturing capabilities, by establishing an electronics precedence list which set up a priority system within the priority system which governed all war production. This situation was alleviated to some extent by the consolidation of the Bureau of Engineering and the Bureau of Construction and Repair into the Bureau of Ships on 1 July 1940. Further improvement was brought about by cognizance agreements made between the several bureaus as the war progressed.[2]

Radar is a word coined from a contraction of "radio detection and ranging." Its coinage is attributed to two U.S. naval officers, E. F. Furth [3] and S. P. Tucker,[4] both now retired as rear admirals. On 18 November 1940, the Chief of Naval Operations directed the use of the word as nonclassified for reference to the then secret project.[5] Prior to 1943 the British called it "radiolocation" and "RDF." The U.S.

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[1] In narrating the history of radar it was first thought best to divide it into chapters on search radar, fire-control radar, and airborne radar. As the writing progressed it was found that this approach was confusing. The history of radar is therefore contained in this chapter and an attempt is made to provide a chronological narrative. With the excellent records of the naval bureaus, the assistance of Dr. R. M. Page, of the Naval Research Laboratory, the report of the Joint Board on Scientific Information Policy, and the published reports of the companies available, the author endeavors to credit the contributions of individuals, companies, and laboratories whenever they can be substantiated.

[2] Intra., Chap. XXXVI.

[3] Bown, "Ships, Machinery and Mossbacks," p. 138.

[4] A. Hoyt Taylor, "Radio Reminiscences: A Half Century," Naval Research Laboratory report, p. 363.

[5] Chief of Naval Operations multiple-address letter, dated 18 Nov. 1940, serial 069120.

Army used the term "radio position finding." During that year, by common consent, the term "radar" was adopted by all English-speaking countries.[6] It is a method of locating objects by combining the bearings obtained in one or more planes and the range, determined by the time interval between transmission of a radio pulse from the equipment and the receipt of the echo of that pulse by the same equipment after reflection by objects whose positions are desired.

RADAR PRINCIPLES

In radar systems the transmitter and receiver are normally collocated and utilize a common scanning antenna. The dual use of the antenna is desirable for conservation of space, to assure coalinement of transmitter and receiver antenna patterns, and to simplify the movement of radar beam in azimuth and elevation. Radio energy is transmitted in pulses of about a millionth of a second in duration, the transmitter is then disconnected from the antenna for a few thousandths of a second, then reconnected for transmission of the next pulse, ad infinitum, as long as the set is operated. During the interval the transmitter is disconnected, the receiver is connected to the common antenna, receives the echoes of the preceding pulse from objects in the beam path, and is then disconnected, also ad infinitum. Nearest objects echo signals first and the measure of distance is the elapsed time from pulse to echo multiplied by one-half the speed of light. Bearings of objects are obtained by use of a directional antenna emitting pulses in a sharp beam and upon which the echoed signals impinge. The bearing of the antenna at the time of these dual operations is the relative bearing of the object reflecting the radio waves. For any radar system the beam is narrowed and the gain is increased with an increase in transmitter frequency. For installations where size and weight limitations are controlling factors, higher frequencies are utilized to provide lighter and more compact equipment. Broad beams are generally desirable for search and detection purposes while narrow beams are essential for fire-control purposes.
use a radiofrequency oscillator containing one or more vacuum tubes which will oscillate at the prescribed frequency and trans-

The transmitters of most radar systems mit the necessary bursts of instantaneous, relatively high-power radiofrequency energy to the antenna. The modulator takes power from a primary source and provides the suitable voltage pulses to turn on and drive the oscillator violently for an infinitesimal part of a second, turn it off sharply, and keep it quiet during the receiving interval.

The receiver, although quite small, is an ingenious and complicated piece of equipment. Normally, the superheterodyne principle is used to provide an intermediate frequency which is then highly amplified. The pulse signals require the utilization of receivers of instantaneous response. This necessitates the use of highly specialized, short time-constant circuits. The final stages of the receiver must modulate the signals for suitable presentation to the indicator.

Radar antennas must be extremely directional, highly efficient, and must leak off none of the power into side lobes since these lobes might produce confusing signals. They must be capable of being directed both vertically and horizontally.

In many radar systems a low-voltage cathode ray tube is used as the indicator which presents the information in several different forms. This tube became commercially available following its development by the Bell Telephone Laboratories in 1923. In the simplest type of tube the electron beam is given a deflection proportional to time in one direction and to the strength of the echo signal in the other. The position plan indicator tube, with a residual glow screen, measures time from the center of the tube

[6] Joint Board on Scientific Information Policy, "Radar, a Report on Science at War," Washington, Government Printing Office, 1945, p. 9.

and outward radially in the direction in which the antenna is trained. This type of indicator was developed by Dr. R. N. Page, of the Naval Research Laboratory, during 1941.

EARLY KNOWLEDGE OF RADIO WAVE ECHOES

The only difference in radio, heat, and light waves is that of frequency. In 1886, Heinrich Hertz, who discovered the existence of radio waves, demonstrated that these waves were reflected by solid objects. In 1904, patents were granted in several countries on a proposed method of utilizing this property as an obstacle detector and as a navigational aid for ships. Suitable eqiupment was not developed for these purposes, and the idea remained dormant for almost two decades. In June 1922, Marconi revived it with the suggestion that high frequencies might be used for the radio detection of objects.[7]

MILITARY INTEREST IN RADIO DETECTION

Military interest in radio detection was awakened in the fall of 1922 when Dr. A. Hoyt Taylor, who has been given the appellation "Father of Radar," and Mr. Leo Young, both of the Naval Aircraft Radio Laboratory, noted distortion in received signals caused by their reflection from the S.S. *Dorchester*, a wooden steamer plying the Potomac River. This discovery was reported to the Navy Department with the suggestion that—

> destroyers located on a line a number of miles apart could be immediately aware of the passage of an enemy vessel between any two destroyers of the line, irrespective of fog, darkness, or smoke screen.

No action was taken on this suggestion at that time.[8]

Since a pulse-transmission system had not been developed at the time, there was no possible way of receiving the echoed signals except by use of a receiver located some distance from the transmitter. The presence of moving objects was detectable by the out-of-phase reception of the transmitted groundwave and the reflection of the wave from the object back to the same receiver.

In June 1930, Mr. L. A. Hyland, an engineer of the Naval Research Laboratory, which had absorbed the Naval Aircraft Laboratory in 1923, was testing a high-frequency direction finder in an airplane on the ground. The Laboratory was emitting radio signals on 32.8 mc. from a horizontally polarized antenna. The plane was equipped with a 15-foot horizontal antenna with the connection to the receiver at about the midpoint. By swinging the plane he was able to obtain a very sharp minimum on the transmissions. While conducting these tests Hyland noted that whenever an airplane appeared in the air nearby, the minimum was disturbed by reflected signals.[9] He reported this to Dr. Taylor, who was then Superintendent of the Radio Division of the Laboratory. Further tests confirmed Hyland's report. In November 1930, the Director, Naval Research Laboratory, submitted the Bureau of Engineering a detailed report on "Radio-Echo Signals From Moving Objects." [10] Shortly after receipt of this report, the Bureau directed the Laboratory to "investigate the use of radio to detect the presence of enemy vessels and aircraft." [11]

Following the Bureau's directive, further experiments with radio wave echoes from aircraft were carried out, utilizing the personnel of the Aircraft Section of the Radio Division of the Laboratory under Mr. C. B. Mirick. This experimentation was expanded to cover frequencies up to about 100 mc. by utilizing portable equipment

[7] Ibid., p. 4.

[8] Memorandum, dated 27 Sept. 1922, commanding officer, Naval Air Station, Anacostia, D.C., to Chief of the Bureau of Engineering.

[9] A. Hoyt Taylor, op. cit., p. 267.

[10] Letter, dated 5 Nov. 1930, Naval Research Laboratory, file C–F42–1/67 (E4222).

[11] Bureau of Engineering Problem Specification No. Bl–1, dated 25 Nov. 1930.

operated in various locations within 30 miles of Washington. A complete system was devised for the protection of an area of 30 miles in diameter prior to 1932. The protection of this area required the installation of a set of transmitters of moderate power, coupled to directional antennas, operating on frequencies near 100 mc. located around the periphery of a circle enclosing the area. Each transmitter emitted a fan beam directed away from the protected area. Within a few miles these beams gradually overlapped each other. Receivers were located on another circle 15 miles farther out along the beams with their outputs connected by landlines to a central station. Enough of the components of the system were constructed and installed to prove that the presence of aircraft could be detected and their approximate location given when they were within 50 miles of the center of the area to be protected. In the system, detection was afforded by the interferences to the groundwaves traveling directly to the receiver by the radio waves reflected from the aircraft and thence to the receiver, the latter traveling the longer distance, thus establishing an out-of-phase relationship.[12]

Since this system was not adaptable to shipboard usage, the Secretary of the Navy, in late 1932, suggested that it might meet the requirements of the Army. That service evinced interest and considered awarding a development contract to the Geeral Electric Co., but before negotiations were completed more effective developments occurred.[13]

Pulse transmissions, soon found essential for the successful application of radar principles, were first experimented with for measuring distances in 1925 by Drs. Breit and Tuve, of the Carnegie Institution of Washington, aided by Mr. Leo Young, of the Naval Research Laboratory. These experiments proved successful, and the method soon came into use by other countries for determining ionospheric changes. This resulted in rapid improvements in techniques. Radar really came into existence when it occurred to Young, in March 1934, that pulse transmission might provide a solution to the problems arising from collocating the transmitter and receiver. A year later the same idea occurred to Watson-Webb, who was conducting the British effort in this field.[14] Following this, secret work was conducted in many countries involving research in problems of increased power, short pulses, and highly directional antenna systems.[15]

Meanwhile, personnel of some industrial laboratories in this country had noted reflection phenomenon. Engineers of the Bell Telephone Laboratories had discussed the subject in an open meeting of the Washington Chapter of the Institute of Radio Engineers on 12 January 1933.[16]

RADAR COMPONENT DEVELOPMENT NECESSARY FOR UTILIZATION OF HIGHER FREQUENCIES

Experimentation with the use of higher frequencies for communication purposes was being conducted at commercial and military laboratories. This involved problems in the development of vacuum tubes which would provide sufficient power at the higher frequencies and a means of transferring high-frequency energy from the transmitter to the antenna. At frequencies up to about 200 mc. conventional, available tubes could be driven to provide adequate power for pulse transmissions. This was sufficient to provide long-range surveillance against aircraft, but the use of higher frequencies was necessary to insure the precision necessary for gunfire control. The

[12] A. Hoyt Taylor, op. cit., pp. 268, 269.

[13] Ibid., pp. 269, 270.

[14] Statement of Dr. R. N. Page, Naval Research Laboratory, to the author on 15 Apr. 1959.

[15] Joint Board on Scientific Information Policy, op. cit., p. 5.

[16] Letter, dated 19 Jan. 1933, Director, Naval Research Laboratory to Chief of the Bureau of Engineering, file C–S67/43 (4972).

losses in normal types of conductors at frequencies above 100 mc. prohibited their use and were a definite hazard in shipboard installations.

Several laboratories in this country were of the opinion that they possessed the requisite talent to produce a satisfactory tube for use at the higher frequencies. This was especially true of the Bell Telephone Laboratories. Development projects were established. Despite intense effort, no success had been obtained by October 1940 and no apparent solution was envisaged. Meanwhile, war had commenced in Europe. The British, with their island fortress subject to German bomber attacks, required a long-range surveillance system for protection. The old adage, "Necessity is the mother of invention," proved true in this case. British scientists took an American invention, the cavity magnetron, and improved it to where it was capable of generating enormous surges of radio energy at ultrahigh frequencies.[17] This device was invented by Dr. A. W. Hull, of the General Electric Co., in 1921. No practical use was found for it at that time. Scientists of several nations improved it, but failed to appreciate its power potential. In this country Mr. W. F. Curtis, of the Naval Research Laboratory, did important work with magnetrons at about 750 mc. in 1934. Two years later, Messrs. Philpott, Cleeton, and Hagen, of that Laboratory, were using the tube to produce oscillations at 3,000 mc., but did not achieve sufficient reliability to make its operational use feasible.[18]

The problem of satisfactory high-frequency conductors was temporarily solved by the radio industry. Their interest in assisting the military in this field was intensified by their desire to utilize higher frequencies for communications and by the advent of television. The Bell Telephone Laboratories developed a semiflexible copper coaxial tubing, and other companies were soon producing similar types of transmission lines of an even more flexible type.[19] These coaxial lines solved the immediate problem, but as the frequency and power of radar equipment increased the losses in this type of conductor became too excessive. Waveguides which had been developed by Mr. G. C. Southworth, of the Bell Telephone Laboratories, for communications purposes were then adapted to radar.[20]

NAVY RESEARCH AND DEVELOPMENT OF PULSE RADAR SYSTEMS

At the time Young came forward with the suggestion of using pulse transmissions in radar, a special Research Section was organized under him to actively push forward in this and other high-frequency problems. Dr. R. M. Page was immediately placed in charge of the radar project and later was assigned Messrs. L. R. Philpott, R. C. Guthrie, and A. A. Varela as assistants. The selection of Page to head this group was fortunate, for he possesses great ability and has an inventive mind. Taylor credits him with contributing more new ideas in the radar field than any other single individual.[21]

Shortly before this, the Director, Naval Research Laboratory, had advised the Chief of the Bureau of Ordnance by letter about the possibilities of controlling gunfire by microwave radio.[22] This letter was referred to the Special Board of Ordnance for study. One of the conclusions of this board set forth in a memorandum, dated 20 March 1934, stated that—

> —if the development of the application of radio microwaves was to be accelerated, which in view of its military importance appears to be highly desirable incentive must be supplied or the work must be done by the Army and Navy.

[17] Buford Rowland and William B. Boyd, "Navy Bureau of Ordnance in World War II," Washington, Government Printing Office, 1953, p. 418.

[18] A. Hoyt Taylor, op. cit., pp. 306, 307.

[19] Ibid., pp. 293, 294.

[20] "Bureau of Ordnance Source Book on the History of Fire Control Radar," ch. 1, p. 10.

[21] A. Hoyt Taylor, op. cit., pp. 270, 271, 295.

[22] Letter, dated 15 Sept. 1933, Naval Research Laboratory to the Chief of the Bureau of Ordnance.

During 1934, Page designed and constructed the first pulse radar transmitter operating at 60 mc.[23] During tests conducted in December with improvised receiving apparatus, saturation signals were received from a small airplane at 1 mile. The following year was spent solving the problems peculiar to reception of microsecond pulses with an extremely high gain receiver in the immediate proximity of a transmitter radiating many kilowatts in pulses on the same frequency. New equipment was constructed to operate of 28.6 mc. to utilize an existing large beam antenna built to that frequency. At the suggestion of Philpott a self-keying transmitter was utilized. This transmitter and auxiliary components were built by Guthrie, who assisted Page in the system assembly and trials.[24]

Trials of this newly constructed radar equipment were commenced in late April 1936 and were continued throughout May with great success. Aircraft were detected and located at ranges up to 25 miles, the limit of the range scale used. The equipment was shown and its operation demonstrated to high Navy Department officials on 10 June 1936.[25] A team of electronic engineers of the Navy, consisting of Page, Philpott, and Guthrie under the direction of Young, demonstrated a more sophisticated system, the success of which was nothing short of spectacular. However, additional development was necessary before it could be adapted to shipboard installation. On 12 June, Rear Adm. H. G. Bowen, USN, Chief of the Bureau of Engineering, classified the project as secret and directed that it be given the highest possible priority.[26]

Shipboard installation necessitated the use of a much smaller antenna. This was accomplished by two major developments; 200-mc. radar and common use of one antenna for both transmitting and receiving. In 1 month Varela developed this transmitter and made it suitable for trials. Following a suggestion by Young, Page developed a duplexer for common antenna use at 200 mc. This ingenious device, which connects the transmitter and disconnects the receiver and vice versa for the infinitesimal periods of time necessary to prevent paralyzation of the receiver during transmission and yet allow it to be connected for the reception of the reflected radio waves, was successfully incorporated in the equipment. It later became common to all radar equipments.[27] In 1954, Young and Page were granted a U.S. patent on this component.

By August 1936, 200-mc. radar with one antenna for transmitting and receiving was a reality in the laboratory. It required 18 months to raise this embryonic equipment to the stature of power, sensitivity, and reliability that justified design for service use, and another year to perfect it into a piece of finished service equipment.

On 18 January 1937, the Naval Research Laboratory was directed to demonstrate and make complete disclosures of its radar development to representatives from the U.S. Army Signal Corps Laboratory, Fort Monmouth, N.J.[28] At that time the Signal Corps Laboratory had not succeeded in developing a satisfactory pulse transmission system. Later, on 30 July 1937, the Signal Corps demonstrated a pulse-type radar based upon development work accomplished after the demonstration of the Navy equipment.

In April 1937, the Honorable Charles Edison, Assistant Secretary of the Navy,

[23] Letter, dated 9 Sept. 1935, Director, Naval Research Laboratory, to the Chief of the Bureau of Engineering, file C–49–4/ENO WF–2.

[24] Statement of Dr. R. M. Page, Naval Research Laboratory, 11 Sept. 1961.

[25] Letter, dated 29 May 1936, Director, Naval Research Laboratory, to Chief of the Bureau of Engineering, file C–49–4/Eo8) W5–2S) ; statement of Dr. R. M. Page, Naval Research Laboratory, 11 Sept. 1961.

[26] Letter, dated 12 June 1936, Chief of the Bureau of Engineering to the Director, Naval Research Laboratory, file C–S/67/36 (6–10–W9) .

[27] Joint Board on Scientific Information Policy, op. cit., pp. 5–6.

[28] Letter, dated 18 Jan. 1937, Chief of the Bureau of Engineering to Director, Naval Research Laboratory, file C–F42–1/69.

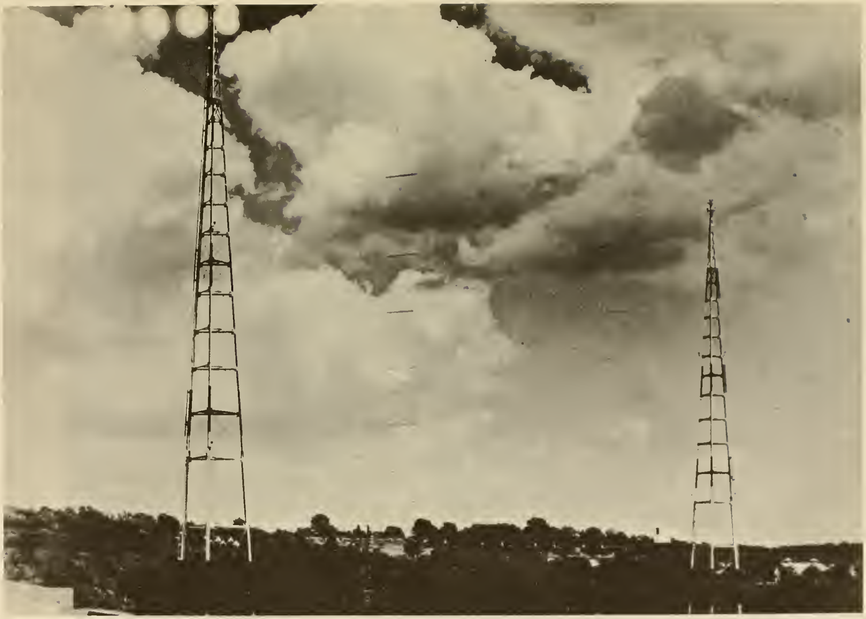

FIGURE 38–1. 28 Megacycle radar antenna used by U.S. Naval Research Laboratory for detection of aircraft by beat method in 1930, and for radar (pulse technique) in 1936.

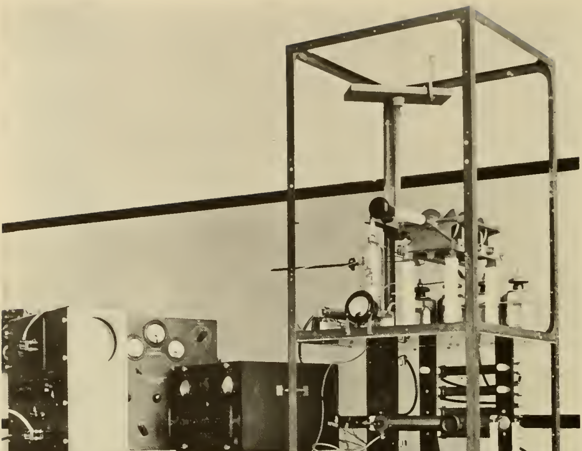

FIGURE 38–2. U.S. Naval Research Laboratory experimental pulse radar transmitter, 1936.

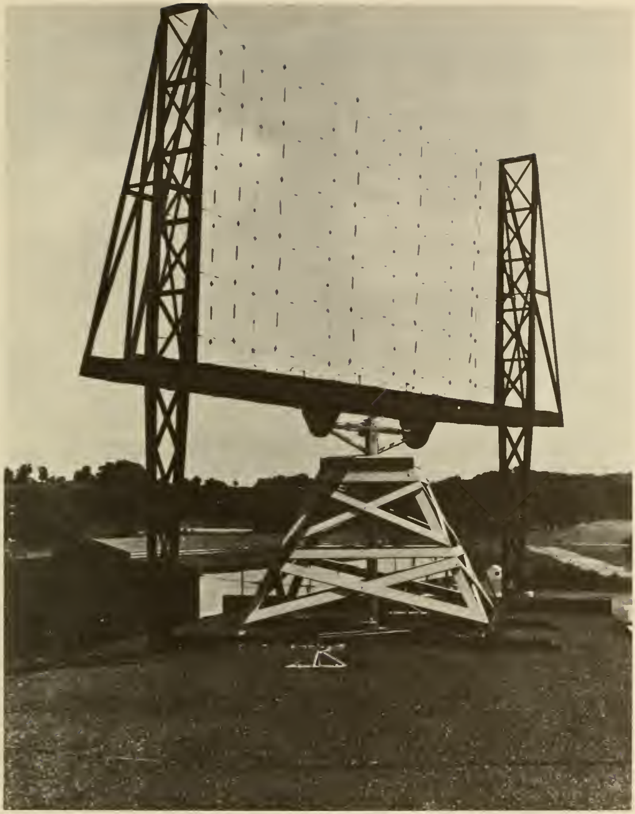

FIGURE 38–3. First rotating beam radar antenna (for 200 Mc radar used for transmitting and receiving) which was developed by U.S. Naval Research Laboratory in 1937.

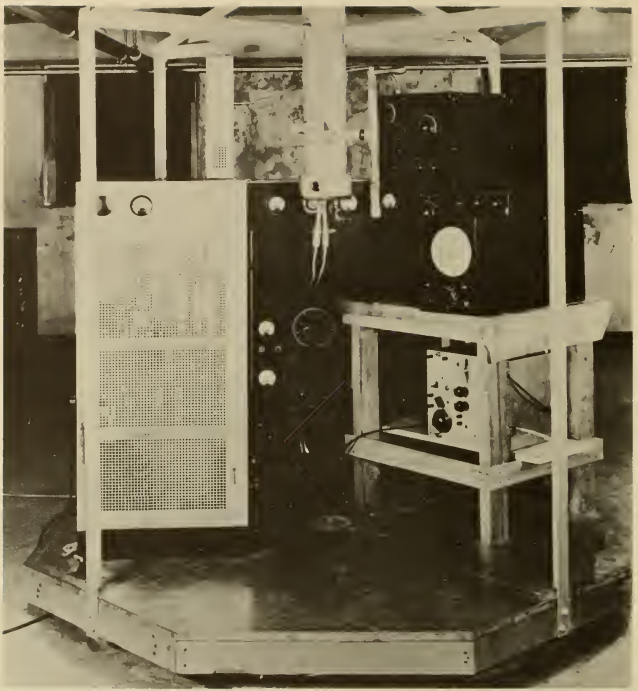

FIGURE 38–1. First rotating beam radar (200 Mc radar used for transmitting and receiving) which was developed by the U.S. Naval Research Laboratory in 1937.

and Adm. William D. Leahy, USN, Chief of Naval Operations, witnessed a demonstration of radar equipment at the Naval Research Laboratory, became convinced of its capabilities, and thereafter ardently supported the project.[29] The U.S.S. *Leary*, an old four-stack destroyer, was concurrently made available for testing the equip-

[29] Joint Board on Scientific Information Policy, op. cit., p. 6.

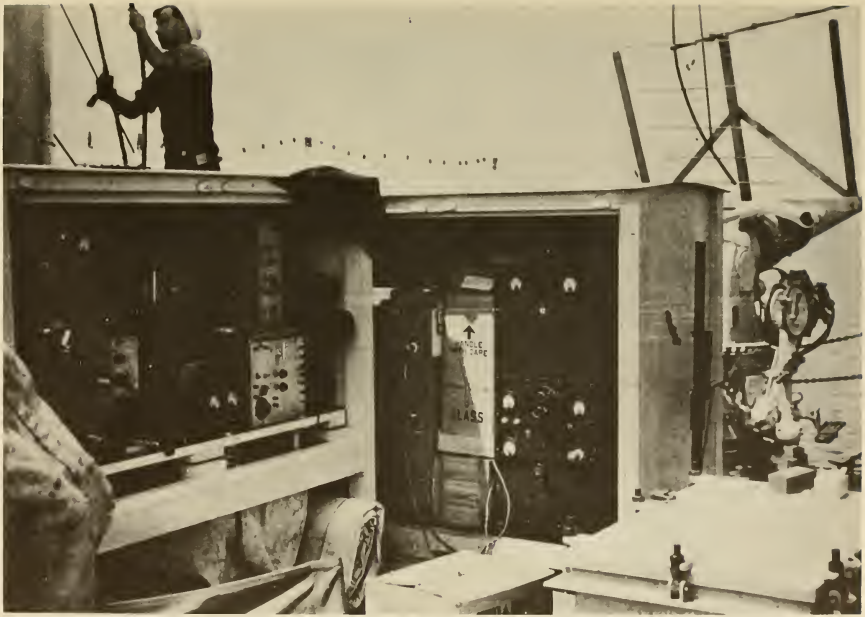

FIGURE 38–5. U.S. Naval Research Laboratory's radar equipment shown on USS *Leary* in April 1937. First test of radar on shipboard. (Note antenna mounted on gunbarrel at right)

ment at sea. The 200-mc. radar set constructed the previous year was temporarily installed with the antenna affixed to a 5-inch gun mount in order that it might be trained in azimuth and elevation.[30]

This radar located planes at ranges of 18 miles during the seaborne tests. Ranges were limited because of the small amount of power which could be generated by available triodes at the frequency necessitated by the size of the antenna. Taylor later stated that he was much encouraged at this time because it was shown that radar would work under seagoing conditions, without seriously interfering with other equipment, and that he was aware of numerous improvements which could be made to greatly increase its range and reliability.[31]

On 13 July 1937, at the direction of the Chief of the Bureau of Engineering, complete disclosure of all technical details of radar development were made to engineers of the Bell Telephone Laboratories in the hope that their affiliate, the Western Electric Co., might accept a contract for the development of an engineered equipment for shipboard test.[32] These engineers stated that the Naval Research Laboratory had "very beautifully" laid research foundations and demonstrated ultimate feasibility, but that an enormous amount of practical development was necessary. They agreed upon the importance of having special tubes designed for the work, and considered that their Laboratory "had the talent to design such tubes." [33] After this conference, the Western Electric Co. officials decided to withhold bidding on an engineered model of the Research Laboratory equipment and, in lieu thereof, to make a proposal for the development of a 700-mc. equipment.[34]

Meanwhile, the Laboratory continued its development of 200-mc. radar. The most pressing need was an oscillator capable of generating the required power at that frequency. In November 1937, Page suggested the use of a "multiple-tube, ring-mounted transmitting oscillator." [35] This suggestion was developed by him with the assistance of Guthrie and Varela and resulted in the construction of a series of multiple-tube oscillators at very high frequency, in which efficiency was not degraded by adding up to 12 tubes in each oscillator. The 100TH tube developed by Eitel-McCullough, Inc., for use in amateur radio transmitters was selected for use in the multiple-tube oscillator. At their rated plate voltage of 3-kv. they could scarcely be made to oscillate at a frequency of 200 mc., but in a six-tube ring, pulsed at 15 kv., they generated over 1kw. per tube pulse power.[36] This new oscillator was incorporated in a "breadboard" model of 200 mc. equipment, and placed under test at the Laboratory early in 1938 where it was successful in detecting planes up to ranges of 100 miles.[37]

NAVY SERVICE TESTS OF SHIPBORNE RADAR

A conference, attended by representatives of the Chief of Naval Operations, the Naval Research Laboratory, and interested bureaus, was held on 24 February 1938. At this time representatives of the Chief of Naval Operations demanded that a model of the Laboratory equipment be placed in the fleet for detection purposes. The Chief of the Bureau of Ordnance concurred, but asked that the development of radar for fire-control purposes be contin-

[30] A. Hoyt Taylor, op. cit., p. 300.

[31] Ibid., p. 303.

[32] Statement of Mr. J. W. Smith, of the Bell Telephone Laboratories.

[33] Conference Report, dated 16 July 1937, Director, Naval Research Laboratory, file C-S67/36.

[34] Statement of Mr. J. W. Smith, of the Bell Telephone Laboratories.

[35] Statement of Dr. R. N. Page to the author on 14 Apr. 1959.

[36] Naval Research Laboratory Records of Consultive Services, dated 27 Apr. 1938, 19 Sept. 1938, and 23 Sept. 1938.

[37] Letter, dated 18 Nov. 1944, Eitel-McCullough, Inc., to Radiation Laboratory, Massachusetts Institute of Technology.

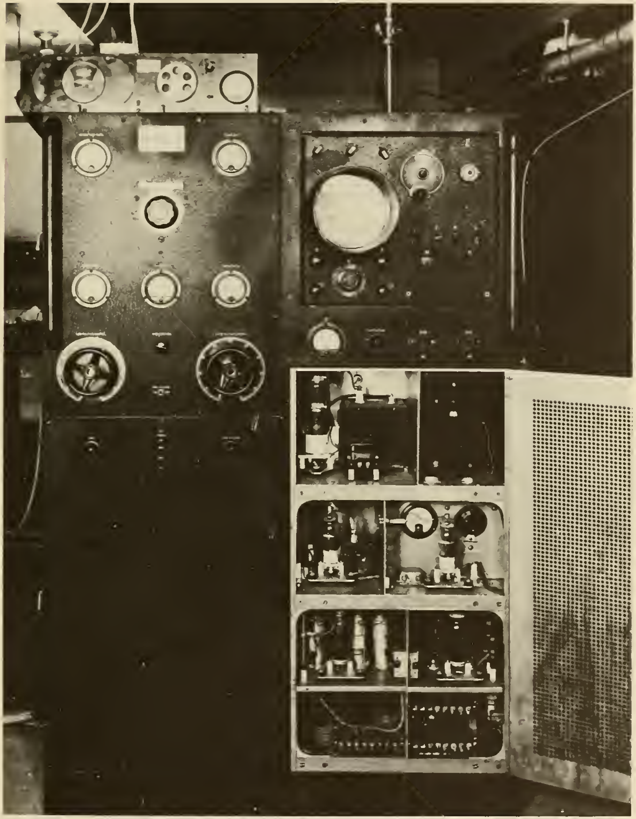

FIGURE 38–6. XAF radar (transmitter and receiver) which was installed on USS *New York* by U.S. Naval Research Laboratory in 1938.

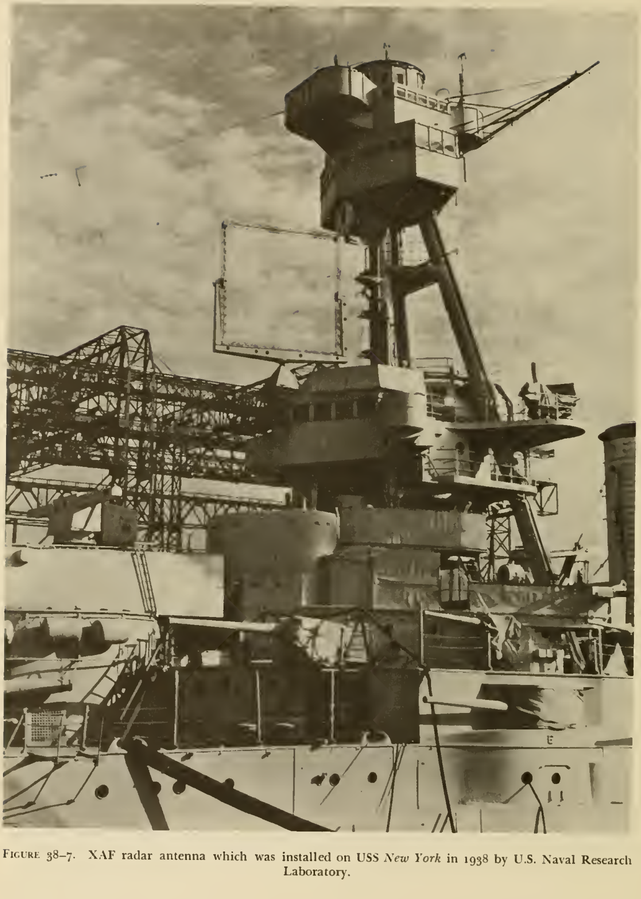

FIGURE 38–7. XAF radar antenna which was installed on USS *New York* in 1938 by U.S. Naval Research Laboratory.

ued.[38] The Laboratory was to complete the construction of a 200-mc. radar for installation in a ship, prior to the end of the year, for service tests. The U.S.S. *New York* was selected for the experimental installation of this equipment, which was given the designation "XAF." The top of the conning tower, located just forward of the foremast, was selected for the antenna installation which, because of its size, about 17 feet square, and appearance, was dubbed the "flying mattress." Installation was completed during December 1938. During March 1938 the Bureau of Engineering disclosed the basic principles of radar to designated engineers of the Radio Corp. of America and contracted with that company for the development of an experimental set in the 400-mc. band. The contract required that this be ready for installation and test by the end of 1938. This was a difficult requirement because of the limited experience of these engineers in the radar field. Nevertheless, the equipment, designated CXZ, although not satisfactorily developed, was installed in the U.S.S. *Texas* during December 1938.[39] It is of interest to note that the cost of the XAF was less than $17,000 as compared with the $60,000 paid for the CXZ.[40]

The huge rotating antenna for the XAF, which had to be built as light as possible consistent with strength necessary to withstand high wind pressures, was constructed by the Brewster Aeronautical Corp. This company was experienced in duralumin construction.[41]

Both equipments were given exhaustive tests during winter maneuvers and battle practices in the Caribbean. As a result of the too-short period allowed the Radio Corp. engineers to develop the CXZ, the XAF was better engineered. The higher frequency of the CXZ permitted use of a much smaller antenna.

The Naval Research Laboratory equipment proved ever more satisfactory and reliable than was expected. It operated for nearly 3 months on an average of almost 20 hours a day. There were only two breakdowns in the entire period, both of which were due to tube failures and were corrected immediately by replacement of the faulty tubes. It was used for navigational purposes, for surface and air detection, for spotting the fall of shot, and, to the surprise of all, for tracking projectiles in flight.[42]

Unfortunately, the hastily designed and constructed CXZ was unable to produce good results, but the Radio Corp. engineers learned enough to insure that their next model would be more practical.[43]

The unsatisfactory state of development of the CXZ radar resulted in the Chief of the Bureau of Engineering recommending to the Chief of Naval Operations that a full exchange of technical information be permitted between the radar groups of the Naval Research Laboratory and the Radio Corp. of America. He considered this a necessary educational program for the commercial companies which would have to do much of the final development and engineering prior to quantity production.[44]

Upon the completion of tests Capt. R. M. Griffin, USN, commanding the U.S.S. *New York,* recommended the XAF be installed immediately on all Navy aircraft carriers. Rear Adm. A. W. Johnson, USN, Commander, Atlantic Squadron, in forwarding the *New York* report, stated, "The XAF equipment is one of the most important military developments since the advent of radio itself. The development of the equipment is such as to make it now a permanent installation in cruisers and

[38] Record of conference held at Bureau of Engineering on 24 Feb. 1938 ("Bureau of Ordnance Source Book on the History of Fire Control Radar," ch. 2, p. 9).

[39] A. Hoyt Taylor, op. cit., pp. 324–328.

[40] "Bureau of Ordnance Source Book on the History of Fire Control Radar," ch. 2, p. 22.

[41] A. Hoyt Taylor, op. cit., pp. 324–328.

[42] Ibid., pp. 328–332.

[43] Ibid., p. 335.

[44] Letter, dated 19 Dec. 1938, Chief of the Bureau of Engineering to the Chief of Naval Operations, serial 292.

carriers." [45] The Commanding Officer, U.S.S. *Texas,* considered the CXZ, as installed, of little value, but recommended that the Navy Department continue to encourage and assist the Radio Corp. in its development.[46]

INITIAL NAVY PROCUREMENT OF COMMERCIALLY ENGINEERED RADARS

On 1 May 1939, the Chief of Naval Operations held a policy conference to reach decisions concerning manufacture and installations of radar equipments. Based upon Page's report and the glowing reports from the Fleet, officers of the Office of the Chief of Naval Operations desired that 20 exact copies of the XAF be procured. The Bureau of Engineering demurred on the ground that further improvement was desirable. A compromise agreement was reached that 10 equipments would be placed under contract.[47]

On 18 May 1939, the details of the XAF radar were disclosed to engineers of the Western Electric Co. Laboratories and on the following day to engineers of the Radio Corp. of America. Prior to 15 June, complete specifications for "radio range equipment" were ready for the prospective bids of the two companies. However, in lieu of contracting for 20 sets as recommended by Operations, the Bureau decided to purchase only 6 sets on the first contract and to later contract for others of an improved version based on knowledge gained under the initial contract.[48]

The contract was awarded the Radio Corp. of America in October 1939, with the understanding that the Naval Research Laboratory would assist in every possible manner. The XAF was delivered to the contractor the following month and the first production models, designated CXAM, were delivered in May 1940. These equipments were fitted in the U.S.S. *California, Yorktown, Chicago, Pennsacola,* and *Northampton.*[49]

The Research Laboratory had succeeded in developing a detection system which would, in the near future, revolutionize naval warfare. Despite this, there was difficulty in procuring sufficient funds to press the project with the necessary rapidity. This stemmed from the natural conservatism of our naval officers and from an economy imposed upon them during the depression of the thirties. Incredible as it may seem, the Bureau of Engineering, in 1939, requested and obtained only $25,000, exclusive of the salaries of its engineers, for electronics research.[50]

INCREASED RADAR DEVELOPMENT BY THE NAVY

Late in 1939, Page submitted a report to Rear Adm. H. G. Bowen, USN, who, upon finishing his term as Chief of the Bureau of Engineering, had become Director, Naval Research Laboratory. This report emphasized that antenna size could be greatly reduced by the utilization of higher frequencies, but that this necessitated awaiting the development of a new type of tube. The report stated that the 500-mc. equipment then under development functioned well up to 20,000 feet; that development was continuing along two lines, one for longer-range detection at about 200 mc. and the second for the use of higher frequencies for altimeter, fire-control, and bombing equipments; and that it was hoped that the Navy would shortly be in a position to use radar on bombing planes. This re-

[45] Letter, dated 24 Mar. 1939, Commanding Officer, U.S.S. *New York,* to Commander, Atlantic Squadron, file BB34/S67/ (71) ; "The First 25 Years of the Naval Research Laboratory," NavExos P–249, p. 47.

[46] Letter, dated 24 Mar. 1939, Commanding Officer, U.S.S. *Texas,* to commander, Atlantic Squadron, file BB35/S67/ (296) .

[47] Statement by Dr. R. N. Page to the author on 14 Apr. 1959; letter, dated 8 May 1939, Chief of Naval Operations, file S–S67/36 Op–20–E/AB.

[48] A. Hoyt Taylor, op. cit., p. 336.

[49] A. Hoyt Taylor, op. cit., p. 336; serial No. 1 was installed in the U.S.S. *California on* 7 Aug. 1940. Following the damage suffered by that vessel on 7 Dec. 1941, it was installed at the Army Base, Oahu, T.H.

[50] "An Administrative History of the Bureau of Ships During World War II," undated and unpublished manuscript, p. 252.

port was forwarded the Secretary of the Navy on 8 December.[51]

Another Laboratory report, addressed to the Bureau of Engineering, dated 26 February 1940, again emphasized the developments of equipments using higher frequencies and stated the importance of integrating recognition equipment with radar. It further emphasized the necessity of integrating radar in the fire-control system and the development of repeater units and the plan position indicator.[52]

On 30 April 1940, seven important phases of radar which should be developed were listed. Because of lack of personnel and facilities, work was proceeding on only basic development, detection of surface vessels and aircraft from both surface and airborne craft, and aircraft detection from submarines. In a letter dated 7 May 1940, the Bureau stated that—

> the inherent possibilities of radar offer compelling reasons for the development of all its phases insofar as consistent with reasonable economy.

In replying to this the Laboratory requested that it be allocated over twice as much money for radar development during the coming fiscal year as had been granted them for the one which was drawing to a close. On 28 May 1940, the Chief of the Bureau of Engineering cautioned against proceeding too rapidly with the program, stating that, unless care were exercised, with rapid changes in this new field, unlimited funds could be expended and that reasonable economy dictated the awaiting of developments.[53]

On 1 June 1940, the Chief of Naval Operations directed a letter to the Chief of the Bureau of Engineering which stated in part:

> In view of the present international situation it is desired that every effort be made to expedite the completion of the development of the project in all its phases and to commence procurement at the earliest possible date that is justified by the success obtained in every subdivision of the project. Accordingly it is suggested that expansion of facilities and personnel be undertaken as soon as funds are in hand.[54]

On 1 July 1940, the Bureau of Engineering and the Bureau of Construction and Repair were consolidated in the newly created Bureau of Ships. The urgings of the Chief of Naval Operations were heeded by the Chief of the new Bureau, Rear Adm. (later vice admiral) S. M. Robinson, USN. A contract for 14 CXAM-1 radar equipments was negotiated with the Radio Corp. of America. The specifications for this new version called for an improved antenna and for amplidyne instead of thyratron control.[55] On 23 July 1940, the Western Electric Co. was awarded the contract for surface fire-control radar equipment operating on 500 mc. At this time a memorandum by the Chief of the new Bureau stated that the radar program initiated by the Chief of Naval Operations would require $10 million in 1941 and $20 million in 1942. Immediate steps were taken to increase the personnel and to provide facilities necessary to insure that the equipment purchased with these funds would meet naval requirements.[56]

It was becoming apparent to many that there was a strong likelihood of our being drawn into the war. With this feeling, there began in the United States an era of enormous scientific development. Inventive imagination exceeded design and development which, in turn, far outstripped engineering and manufacturing capabilities. The problems requiring solution greatly exceeded the personnel and laboratory facilities provided by our Government, commercial, private, and educational institutions.

The electronic engineers of the Naval Research Laboratory were doing all they could with what they had. To them, and to those who provided them with encouragement, must go the credit for the superior electronics installations which existed on

[51] A. Hoyt Taylor, op. cit., p. 347.

[52] Ibid.

[53] Ibid., p. 348.

[54] Ibid.

[55] Letter, dated 12 Oct. 1944, Bureau of Ships, Serial C–916–9229.

[56] A. Hoyt Taylor, op. cit., p. 349.

our combatant vessels during World War II. It was mostly with the equipment designed and developed during this period that the war at sea was fought. In addition to the development of the search radar and the guidance afforded the Bell Telephone Laboratories in their development of fire-control radars, there were other important requirements met by their scientific knowledge and long and arduous hours of labor. Many of these were in other fields of electronics and are covered in other chapters.

Following the development of the CXAM radar, work was immediately commenced to design similar equipment for smaller vessels. This was a 200-mc. search radar of higher power using a much smaller antenna. The Laboratory's model was designated XAR. The contract for engineering and producing this equipment was awarded the General Electric Co. The preproduction models of this equipment were delivered before they were able to equal the performance of the pilot model provided by the Laboratory. These were purchased in large quantities and bore the designation SC. Similar equipment produced a little later by the Radio Corp. of America carried the designation SA. Although these equipments were rendered obsolete by later microwave developments they were used extensively in all theaters.[57]

Another development, which has been previously mentioned, was the plan position indicator. This oscilloscope greatly simplified the radar presentation of the target, by placing the radar transmitter in the center of the screen and target presentation on lines of bearing, either relative or true against range scales emanating from the center of the screen. Development was completed and the indicator placed in production just prior to our entry in the war. It was welcomed by Americans and British alike. After the war, Page was granted a U.S. patent on this invention.[58]

With the increased operational ability of aircraft, there became a serious threat to submarines, and it was realized that some method of aircraft warning was essential. The use of radar for this purpose was difficult because a large directive antenna would offer too much water resistance to a submerged submarine and would be difficult to house. The Research Laboratory was directed to proceed with the development of a warning radar, using a periscope antenna. Target bearing was not made a requirement since the submarine defense against aircraft is in crashdiving. Mr. R. C. Guthrie was assigned the project in March 1940. It was decided to use the 114-mc. band. Later it was taken over and completed by Mr. A. A. Varela. The first production units of the equipment, designated SD, were constructed by the Radio Corp. of America. During the latter years of the war, the Japanese developed an aircraft receiver covering this frequency band and used the radar transmissions for homing, resulting in the loss of a few of our submarines. As with the SA and SC, development of microwave radar equipment rendered the SD obsolete, and these equipments were replaced by others which could not be utilized offensively by the enemy.[59]

One of the earliest requirements for aircraft safety was an altimeter which would indicate relative rather than absolute altitude. At the time pulse transmission was adapted to radar, it was realized that a radio pulse altimeter might become a possibility. With the development of the Young-Page duplexing system it became a reality. Its development, using a 500-mc. transmitter, was completed by the Laboratory and it was placed into production.

In the fall of 1940 the British supplied the Laboratory complete information on their 175-mc. airborne search radar. The Bureau of Ships purchased a quantity of these ASV equipments for installation in patrol planes. The ASV, because of its low frequency and because the British had not developed a duplexing system, required a

[57] Ibid., pp. 365–366.

[58] Ibid., p. 365.

[59] Ibid., pp. 367–369.

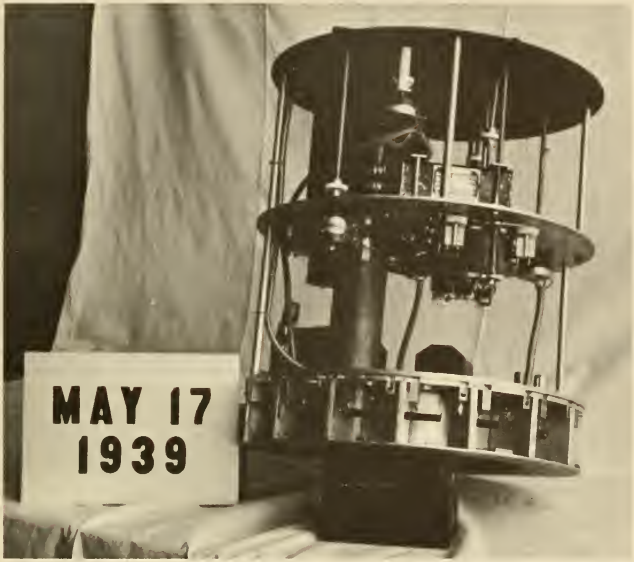

FIGURE 38–8. First pulse altimeter developed by U.S. Naval Research Laboratory in 1939.

number of large antennas. These sets were modified by adding a duplexing system. The Laboratory considered that an airborne search radar would be more efficient, smaller, and lighter if a higher frequency could be utilized. In January 1941, they commenced converting the radio pulse altimeter into an airborne search radar. By October 1941, sufficient information had been provided the Westinghouse Electric & Manufacturing Co. for them to start preproduction models. A month later the Radio Corp. was provided all information on this development and they started work on preproduction models. This American airborne search radar, designated ASB, went into full production in the spring of 1942 with the first equipments being delivered in May. Over 26,000 were produced for American and British military services. Although it, too, became obsolete by the later development of a microwave airborne search radar, many were still being used at the war's end.[60]

During the early months of the war, positive identification of distant aircraft was most difficult. Friendly planes were required to approach naval vessels within

[60] Ibid., pp. 369–370.

a specified variable sector. Even when within the correct sector, they were subject to challenge by searchlight, following which they had to immediately halt progress toward the challenging ship and identify themselves by a periodically varying maneuver and remain away until the challenge was removed. That this was a most unsatisfactory procedure had been earlier recognized. The Naval Research Laboratory personnel had this problem under consideration for several years and were successful in developing several systems integrated with radar, one of which became the basis of the Mark V system adopted by the Allies.[61]

PREWAR RESEARCH AND DEVELOPMENT OF RADAR BY THE ARMY SIGNAL CORPS

The Army had conducted intermittent research on aircraft detection and location systems since the end of World War I. In 1930 the responsibility for research in this field was transferred from the Ordnance Department to the Signal Corps. The project was assigned the Signal Corps Laboratory at Fort Monmouth, N.J., which at the time was under the command of Col. William R. Blair, Signal Corps, USA. Research was instituted in both infrared and radio methods. For the latter the use of microwaves a few centimeters in length was directed. Experiments with these resulted in the obtainment of echoes from nearby objects, but the ranges were not sufficient to make equipment practical for operational use. This prompted Blair to state, in his annual report for fiscal year 1934, that "a new approach to the problem is essential." [62]

When it was suggested by the Secretary of the Navy, in 1932, that the detection system developed by the Naval Research Laboratory might be of more value to the Army than to the Navy, the Laboratory informed the Signal Corps of the development and from that time on there was a complete exchange of information on radar projects by both services.[63] The Signal Corps began negotiations with the General Electric Co. to develop this system. These negotiations were terminated because both the Naval Research Laboratory and the Signal Corps Laboratory began the development of pulse radar systems which appeared to offer greater promise.

The 4 June 1936 demonstration of the Navy's 28-mc. pulse-type equipment was witnessed by Blair and his assistants. They were provided full information concerning the newly developed equipment and were shown the work accomplished on the 200-mc. equipment which was later tested in the U.S.S. *Leary*. During conversations held at that time, Taylor advised Blair to continue work in the 100-mc. band since Army usage was not too severely limited by antenna size. With the lower frequency a much higher peak pulse power could be obtained with available transmitting tubes.[64]

The War Department, on 29 February 1936, directed the Chief Signal Officer to give the highest priority to the development of a detector system for antiaircraft battery use. This directive had been anticipated, and early in 1936 the Signal Corps Laboratory designed a complete radar system. The technique utilized failed to give the necessary instantaneous peak pulse power, but by the end of 1936 some echoes from pulses directed at commercial planes flying on a regular airway in New Jersey had been detected. On 18 January 1937, representatives of the Signal Corps Laboratory were shown the pulsing technique developed by the Naval Research Laboratory. Based upon this information they redesigned their equipment. On 30 July 1937, the pilot model of this redesigned system, later designated SCR 268, was successfully demon-

[61] Ibid., p. 367. Statement of Dr. R. M. Page, Naval Research Laboratory, 11 Sept. 1961.

[62] Joint Board on Scientific Information Policy, op. cit., p. 5.

[63] Ibid., pp. 4–5.

[64] A. Hoyt Taylor, op. cit., pp. 298, 299.

strated against a flight of test bombers in the presence of the Secretary of War and several Members of Congress. It transmitted train and elevation information to a director which enabled searchlights to be pointed and trained so that they could be turned on a plane instantly when it came within range.[65]

Following this the equipment was mounted on mobile antiaircraft artillery director trucks, where it replaced the sound locators previously used during periods of low visibility. In November 1938, this was demonstrated to the Army Coast Artillery Board which shortly thereafter requested the Chief Signal Officer to produce "a radio detection device which will provide accurate azimuth, accurate angular height, and accurate slant range for use as basic firing data for antiaircraft guns." [66]

Acting upon this request, the SCR 268 was improved in accuracy and modified to feed its output to an automatic calculator, the output of which, in turn, was fed to the gun directors. While this equipment was not extremely accurate, it was used in all theaters of operation during World War II and was the backbone of the early warning system installed along our coasts and in our insular possessions.[67]

The Signal Corps made no contribution to the development of airborne radar. The British ASV, the U.S. Navy's ASB, and the Radiation Laboratory's microwave ASV were utilized successively by the U.S. Army Air Force.[68]

PREWAR DEVELOPMENT OF FIRE-CONTROL RADAR

Following the decision of Western Electric Co. officials to develop radar equipment using frequencies in the spectrum between 500 and 700 mc., its parent corporation, the American Telephone & Telegraph Co., agreed to underwrite a research project for the preliminary investigation of radio object locations systems in an amount not to exceed $50,000. Assured of financial support, the Bell Telephone Laboratories, corporate associate of Western Electric, prepared a "Preliminary Development Estimate for U.S. Navy Project No. 2," covering the work proposed to be carried out between 1 April 1938 and 15 December 1939. This consisted of the following problems: (1) The determination of minimum sizes and types of projectors required to obtain the requisite directivity utilizing frequencies in the 300–700-mc. band; (2) the determination of the required instantaneous power in the transmitted pulse to obtain desired ranges from transmitters operating in the 300–700-mc. band; and (3) the determination of the required duration of the transmitted pulse and the degree of precision necessary in measuring the elapsed time between transmission and reception. During October 1937, Dr. F. B. Jewett, Director of the Laboratories, discussed this developmental program with naval officials, and an informal agreement was reached. The American Telephone & Telegraph Co. subsidiaries started work on their project to determine for themselves the requirements, capabilities, and limitations of this new technique. At this time selected engineers from their laboratories were given complete information on the Naval Research Laboratory's work and were thereafter kept advised of Navy progress in the field.[69]

The Bell Telephone Laboratories established a field laboratory near Whippany, N.J., and on 1 May 1938 assigned Messrs. W. C. Tinus, W. M. Kellogg, and A. G. Fox to make the required determinations. Other divisions of the Laboratories were assigned projects to develop satisfactory components.

[65] Joint Board on Scientific Information Policy, op. cit., p. 6.

[66] Joint Board on Scientific Information Policy, op. cit., p. 17.

[67] Ibid.

[68] Ibid., p. 29.

[69] "Bureau of Ordnance Source Book on the History of Fire Control Radar," ch. 3, pp. 1–4.

By May 1939, an equipment operating at 500 mc. had been designed, assembled, and tested. These tests indicated that the precision obtainable with existing techniques was sufficient to make the device useful for certain military and commercial applications but not for the control of gunfire. The $50,000 made available in 1937 was expended by July 1939. The American Telephone & Telegraph Co. authorized the expenditure of an additional $20,000 for continued investigation and improvement of the system. Following improvement which resulted from this, the Western Electric Co., on 15 August 1939, submitted the Bureau of Engineering a proposal with descriptive specifications for the construction of a fire-control radar operating at 500 mc. In April 1940, the Western Electric Co. was issued a development contract for one fire-control radar, designated CXAS, with a delivery date of 15 October of the same year.[70]

A series of exchanges of information between engineers of the Naval Research Laboratory and Bell Laboratories during the first months of 1940 resulted in improvement in techniques and components and necessitated a revision of the specifications. The revisions were submitted and accepted by the Navy on 19 August 1940. Incorporating the improvements resulted in an acceptable delay in delivery of about 2 months.[71]

The development model of the CXAS was tested during December at Atlantic Highlands, the scene of earlier naval radio experimentation. On 30 December, the equipment was delivered to the Navy. The oscillator, consisting of two triodes in push-pull, produced instantaneous peak pulse power of 2 kw. The Young-Page duplexer was utilized.[72]

When, on 2 December 1940, it appeared that the CXAS equipment would meet the specification, an additional contract was issued the Western Electric Co. for 10 model CXAS–1 equipments. They were purchased for installation in the main battery fire-control systems of one heavy and nine light cruisers. This designation of the CXAS–1 was subsequently changed to Model FA.[73]

Production of Model FA radars commenced in June 1941. Serial No. 1 was delivered at the end of that month and installed during the following month in the U.S.S. *Wichita*. An excerpt from this ship's report on the first 525 hours of operation of this equipment is quoted:

> Though the Model FA equipment is intended primarily as an ordnance range finder its greatest value at present lies in its ability to detect and the security furnished thereby. With this in mind it was decided to operate the radar continuously while cruising outside United States territorial waters. Continuous operation was maintained successfully for about thirty-six hours, the only interruptions being those necessary for frequent oscillator tube renewals. During this period the sea was calm and several targets were located. It is interesting to note that two expected transports (high free board) were located at 55,000 yards and became distinguishable as two vessels at 44,000 yards. Several detections were made between 20,000 and 30,000 yards but poor visibility prevented identification of targets. In general the operators were seamen with some training but little operational experience, nevertheless the results obtained were satisfactory and demonstrated the practicability of shipboard use.[74]

The FA radar performed satisfactorily when operating at peak performance, but this performance was difficult to maintain because of the relatively short life (about 75 hours) of the oscillator tubes. The operator was required to swing the antenna back and forth manually while watching the oscilloscope, during which time he estimated the range. Continuous target tracking could be accomplished if a more sensitive means of detecting target movement with respect to beam axis could be developed,[75] and this was eventually achieved.

The Bureau of Ships radar personnel conferred with those of the Bureau of Ord-

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[70] Ibid., pp. 1–7.

[71] Ibid.

[72] Ibid.

[73] Ibid., p. 8.

[74] Letter, dated 20 Aug. 1941, Commanding Officer, U.S.S. *Wichita*, to the Chief of the Bureau of Ships.

[75] "Bureau of Ordnance Source Book on the History of Fire Control Radar," ch. 3, pp. 8–11.

nance and Bell Telephone Laboratories on 14 February 1941. The purpose of this meeting was to determine whether a further modification of the Model FA radar could be accomplished to satisfy the requirements of the Bureau of Ordnance for a continuous tracking radar for each main battery and each antiaircraft gun director. The Bureau of Ordnance representatives suggested separating the console of the Model FA and locating the controls of the equipment and the indicator in the gun director. The Bell Telephone Laboratories representatives accomplished this prior to June 1941. By this time the Bell Telephone Laboratories had incorporated "lobing," a means of remotely and rapidly moving the beam of a highly directive antenna back and forth from its normal axis. A method of incorporating this, along with other essential controls and an indicator for the range operator and another for the azimuth trainer, was evolved. An anticipated requirement for rapidly shifting back and forth between radar and optical controls indicated the desirability that each control operator should handle data from both sources. The radar antenna and the optical rangefinder were interconnected so that both were always trained on the same bearing. This permitted the use of the existing data transmission system and eliminated any break in data transmission when shifting from one method of control to the other. While this desirable development was underway it became obvious that the long-searched-for tube which would provide satisfactory instantaneous peak pulse power might become available.[76]

Following the arrival of the British technical mission in this country in September 1940, mutual disclosures of great value to both countries were made of developments in the radar field. The United States was advised of the British improvement to the cavity magnetron which made it capable of supplying oscillator power in the microwave band. In exchange, British scientists received much needed information concerning the details of the Young-Page duplexing system.[77]

On 3 October, a magnetron of British manufacture was delivered to the Bell Telephone Laboratories. This tube was successfully operated in hastily assembled equipment and in great secrecy on Sunday, 6 October. It produced not less than 6.4-kw. peak power pulses at a frequency of 3000 mc. The best velocity variation tubes existing in this country at that time produced peak power pulse of about 75 watts at that frequency. This tube did, however, generate several additional confusing frequencies. In order to gain further knowledge of its operation and to evaluate its variable elements additional tubes were required. The first multicavity resonator magnetron constructed in this country was completed on 10 October at the Bell Telephone Laboratories electronics laboratory using an X-ray photograph of the British tube in conjunction with some supplementary information provided by the British scientists. On 15 November, five facsimiles were delivered to the Radiation Laboratory, Cambridge, Mass., which had been recently established by the National Defense Research Council for the purpose of conducting microwave research.[78]

Intensified research was conducted at the Bell Telephone Laboratories and the Radiation Laboratory. Attempts were made to apply the same principles to the design of tubes generating both higher and lower frequencies and of higher power and efficiency at all frequencies. Concurrently, Dr. M. J. Kelly, Bell Telephone Laboratories, instituted the development of a 700-mc. magnetron for use in fire-control radars. This tube was completed on 23 December. Just prior to its being tested it was accidentally dropped by the engineer who had been working around the clock to complete it. It was broken beyond repair. A second

[76] Ibid., ch. 5, pp. 1–4.

[77] Statement of Dr. R. N. Page to the author on 14 Apr. 1959.

[78] "Bureau of Ordnance Source Book on the History of Fire Control Radar," ch. 4, p. 8.

700-mc. tube was completed on 14 February 1941 and tested. It produced peak power pulses of 30 kw. Following this, additional improvements were incorporated. A satisfactorily redesigned tube was completed in May and placed in production. The production models produced an output of 40 kw. with an efficiency of approximately 40 percent.[79]

Concurrently with the development of an American 700-mc. magnetron, other Bell engineers were working upon one for utilization at 10,000 mc. This was completed on 18 January 1941. It produced only 9-kw. peak pulse power at less than 10-percent efficiency. In an endeavor to save weight and reduce power requirements they commenced the development of a permanent magnet to replace the electromagnet used in their first 10,000-mc. tube. It was completed and tested on 11 June, at which time it furnished an output of 15 kw. at 20-percent efficiency. Plans were made to place this tube in production but before this could be accomplished the British came forward with still another development.[80]

In November 1941 the Bell Telephone Laboratories were informed that the British group at the Birmingham University had designed and developed a strapped magnetron of improved stability and increased efficiency. About 1 week later the Bell engineers produced their first magnetron of this type. It had an efficiency of 35 percent and a peak pulse power outut of 105 kw. Additional tubes were produced, several of which were sent the Radiation Laboratory for testing and experimental purposes. Following this, good high-power 3000- and 10,000-mc. magnetrons were produced in quantity by the Western Electric and other manufacturing companies.[81]

Following the development of strapped magnetrons, a new transmitter, using the 700-mc. magnetron and two improved triode modulator tubes, was developed and produced. This transmitter provided a peak power output of about 40 kw. with a pulse of about 2 microseconds duration. It resulted in material increase in reliable range with greatly reduced maintenance. It was interchangeable with the one used in Model FA and was applied retroactively to those equipments. Work on the Model FB fire-control radar was discontinued, and the development of two new models designated FC and FD was instituted.[82]

The Model FC was projected for use with fire-control systems against surface targets while the Model FD was for use with 5-inch antiaircraft fire-control systems. As had been planned for in the Model FB, the control console and indicators were remotely located in the directors. Except for the slightly differing requirements of the two fire-control systems and different antennas, both models were identical.[83]

A "breadboard model" of the FC was constructed in June 1941 and put on test at Atlantic Highlands with an antenna modified to permit lobe switching in two planes. Its performance was superior to that of Model FA in every detail.[84]

The first Model FC equipments were delivered in October 1941 and were installed in the forward and after main battery directors of the U.S.S. *Philadelphia* during that month. Prior to 7 December 1941, 10 these equipments had been delivered and were either installed or in process of being installed.[85]

The first Model FD equipment was completed during August 1941 and assembled for test at Atlantic Highlands. On 28 August, an aircraft was tracked out to a distance of 24 miles. On this date it was decided that this equipment would be installed in the U.S.S. *Roe* in conjunction with the first installation of gun director, Mark 37. This installation was completed prior to 22 September and on that date the U.S.S. *Roe* put to sea. Since this was the first antiaircraft fire-control radar installed

[79] Ibid., pp. 8–9.
[80] Ibid., pp. 9–10.
[81] Ibid., p. 10.
[82] Ibid., ch. 4, p. 9; ch. 6, p. 2.
[83] Ibid., ch. 6, p. 1.
[84] Ibid., p. 6.
[85] Ibid., p. 8.

in a combatant vessel, much interest was evinced and many high-ranking officers and scientists were embarked.[86]

The performance of the equipment was good in range and train. Position angle data was poor at long ranges but improved as the targets approached. It was not realized until later that the water reflection caused this rather than malfunction of the equipment.[87]

The only Model FD installed prior to our entry into the war was the one installed in the U.S.S. *Roe*. Delivery of production equipment did not begin until December 1941.[88]

WARTIME DEVELOPMENT OF RADAR UNDER DIRECTION OF OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

The deterioration of the world political situation in 1940 brought about a tremendous expansion of our defense forces. The war in Europe had increased in tempo on the ground, at sea, and in the air. British and German scientists were engaged in a total war, each endeavoring to produce more deadly weapons and to perfect better systems of defense. In the United States the military services were busily engaged in expanding their forces and in training inexperienced personnel. Neither service possessed sufficient scientific personnel to conduct the research essential to keep our defense systems and techniques at the level of those of the major belligerents.

Scientists became deeply concerned because of this. At the suggestion of Dr. F. B. Jewett, President of the American Academy of Sciences, Franklin D. Roosevelt, by Executive order signed 27 June 1940, established the National Defense Research Committee. The mission of this committee was

> to correlate and support scientific research on the mechanisms and devises of warfare.[89]

About one year later this Committee was integrated into and became the operating body of a larger and independent organization, the Office of Scientific Research and Development, under the leadership of Dr. Vannevar Bush.

The Army and Navy were enabled to turn over to scientists, mobilized by the Committee, many problems of a long-range nature as well as a large number of those of uncertain possibilities requiring considerable basic research. One of those, involving radar and radio communications, was that of utilizing the microwave portion of the radiofrequency spectrum. One of the first acts of the Committee was to establish, in July 1940, a Microwave Committee under Dr. Alfred L. Loomis, who had been, for several years, experimenting with the use of this portion of the frequency spectrum at his private laboratory.[90]

At about this time an agreement was reached between the United States and Great Britain for the exchange of scientific information of military nature. As previously mentioned, in September 1940, the British technical mission arrived in Washington for the purpose of effecting such exchanges.

On 12 October, the British technical mission suggested that the United States undertake the development of two urgently required radar systems, a microwave aircraft interception equipment and a microwave antiaircraft fire-control equipment. The suggestion was approved by the Microwave Committee. The Radiation Laboratory, under the administration of the Massachusetts Institute of Technology and staffed by physicists from various universities, was established to develop these systems. It commenced operations in Cambridge, Mass., early in November 1940, under the direction of Dr. Lee A. DuBridge. All available information on the radar

[86] Ibid., p. 6–7.
[87] Ibid., p. 7.
[88] Ibid., p. 8.

[89] Joint Board on Scientific Information Policy, op. cit., p. 9.
[90] Ibid.

developments of the British and American military services, the British scientific effort, and of the Bell Telephone Laboratories was made available to this Laboratory. With basic research completed and the magnetron available, the assigned task was not an impossible one. The Laboratory quickly assumed the leadership in the development of microwave radar equipment.

In order to speed up the development of the airborne interceptor equipment, the National Defense Research Committee contracted with several manufacturers to assist in the development of components. Military hangar facilities were provided at the East Boston Municipal Airport with both military services contributing aircraft for experimental purposes. In January 1941, the Radiation Laboratory obtained echoes from its first microwave equipment using magnetrons provided by the Bell Telephone Laboratories. On 18 March, a laboratory model was tested in a B–18 airplane where it was discovered that the equipment was very effective in locating ships at sea. Prior to the end of May it appeared sufficiently promising to warrant turning it over to the Radio Corp. of America to be engineered for production. By the end of 1941 an airborne microwave set (ASV) for detection of surface vessels had been satisfactorily developed and was ready for production.[91]

A microwave surface search radar was developed concurrently with the ASV. In the late spring of 1941 a "breadboard model" of this equipment, equipped with the Naval Research Laboratory plan position indicator, was installed and successfully tested in the U.S.S. *Semmes,* an old four-stack destroyer. The results obtained led the Navy to award its first production contract for microwave equipment on 30 June 1941. This was the SG radar.

Prior to the end of May 1941 the completely automatic tracking of aircraft had been accomplished by a prototype of the microwave aircraft interception equipment and it appeared to be sufficiently promising to warrant its being engineered for production. By December 1941 a prototype model of Laboratory-designed harbor-defense radar equipment was in operation at the harbor entrance control post at Boston.[92]

By the begining of 1942 an enormous program of microwave radar development was underway in which the laboratories of commercial companies, universities, the Armed Forces of both the United States and Great Britain, and the Office of Scientific Research and Invention all played a cooperative and vital part. By the end of 1943 this new equipment was in large-scale production and was replacing the 500–700-mc. equipments which earlier were installed on our ships for fire control.

[91] Ibid., p. 10.

[92] Joint Board on Scientific Information Policy, op. cit., p. 11.

FIGURE 38–9. USS *Northampton* showing new antenna system utilizing broad-band antennas to provide maximum radiation performance.

CHAPTER XXXIX

Sonar

PROLOG

It has been stated so often as to become axiomatic that new wars are begun using the equipment developed by the end of the last one. Fortunately for us this was not true insofar as underwater detection and location equipment was concerned. As related in part II, much was done during World War I to develop underwater detection equipment, but that which was put into service was not capable of coping with the submarine problem of that war and would have been entirely useless in combating this menace in World War II. Credit for the continued research following World War I and during the depression of the thirties, when practically all research was discontinued, belongs to the several heads of the Radio and Sound Division of the Bureau of Engineering, to Capt. J. T. Tompkins, USN, Commander Control Force, U.S. Fleet, during a part of that period and to the small group of scientists under the indefatigable leadership of Dr. Harvey C. Hayes, the Navy's senior underwater sound physicist.

It is not the writer's intention to imply that the successful development of satisfactory equipment was in itself sufficient to defeat the German submarine threat of World War II. This would be far from the truth, for improvements in equipments, offensive tactics, studies of oceanography, and concentrated studies of both successes and failures in making kills were necessary. It is, however, only fair that it should be pointed out that sonar was the backbone of all that lead to the checking of submarine operations and winning the victory in the Battle of the Atlantic.

At the beginning of World War II the Germans had approximately 20 500-ton and 10 750-ton submarines. The British had fitted 165 destroyers, 34 small patrol craft and 20 trawlers with asdic, their development of underwater detection equipment. During the first year of the war the number of submarines of the Axis Powers was increased by 60 belonging to Italy. By December 1940 these submarines had sunk 1,201 vessels, an average of 80 per month and Allied shipping had suffered a reduction of 4½ million gross tons. In accomplishing this the Axis lost 47 submarines, an average of 3 per month. During 1941 the German submarines commenced "wolf pack" attacks and extended their operations to the coasts of Greenland and Newfoundland, increased the number of their submarines to approximately 200, and sank 1,118 ships for an average of 93 per month. Asdic-sonar equipped Allied vessels, totalling approximately 800, of which 500 were ocean-going, managed to sink 45 submarines for an average of 4 per month.[1]

When the United States entered the war, in December 1941, our 170 destroyers were the only United States surface craft fitted with sonar. Seventy-five percent of these were engaged in Atlantic convoying and the remainder were employed in the Pacific. Our Atlantic seaboard shipping was slaughtered at the rate of 75 ships per month by an operating group of approximately

[1] Sonar Press Release, Office of the Chief of Naval Operations, dated 6 April 1946, pp. 5–6.

38 submarines, which suffered casualties amounting to only 3 per month. Prior to March 1942, we began convoying our coastal shipping with a woefully inadequate number of vessels and land-based aircraft. Our success in sinking submarines, despite successful detection, was less than 5 percent. We were losing the Battle of the Atlantic.[2]

In a desperate attempt to find a solution, the Navy Department assigned the National Defense Research Committee of the Office of Scientific Research and Development, a project to provide statistical analysis of past operations, theoretical studies of tactical doctrines, operational analysis of sonar attacks, and of equipment and weapons in order to determine their best methods of use and to improve their design. The committee established the Antisubmarine Warfare Operational Research Group under the direction of Dr. P. M. Morse, with representatives from practically all Offices of the Fleet Headquarters and a group from the British Admiralty which furnished statistics of the Royal Navy's 30 months of war experience. Our ships began to report attack details to this group which quickly developed improved methods of convoying, screening, searching and attack.[3]

THE DEVELOPMENT OF SONAR

Although research in acoustical sound systems was continued after World War I, it was given low priority because of the high losses encountered during the transfer of propeller noises from water to air. High priority was given to the development of an electrical sonic system since little signal strength is lost by transfer from water to microphones connected electrically to telephone headsets. The greatest emphasis was placed on the development of a supersonic (15,000 or more cycles per second) echo-ranging system, because such a system eliminates much of the inherent ocean noises, utilizes a narrower beam, and the received signal is more easily amplified electronically.[4]

The first experimental sets of this supersonic echo-ranging apparatus were completed prior to 1927 and installed in several naval vessels during that year. They contained a combined transmitting and receiving device called the transducer which consisted of quartz slabs sandwiched between steel discs about 16 inches in diameter. This 4-inch thick assembly protruded through the bottom of the ship. When energized it pinged out pulses of energy of one-quarter second duration, at a frequency between 20,000 and 40,000 cycles per second, which travelled through the water in a sharp cone-shaped beam. Upon striking a solid object a minute portion of the energy was reflected back to the tranducer in the same manner as the radiofrequency energy is reflected in radar. From the transducer this reflected energy was transferred through an electronic amplifier and thence to the headset and a range indicator. The bearing of the reflecting object was indicated by the direction the tranducer was trained. Only a small amount of energy was transferred to the water and echoes were obtainable up to several hundred feet provided the vessel in which it was installed was slowed to 3 or 4 knots. The development of this equipment was an important forward step but obviously the limitations of speed and distance were a serious handicap.[5]

At this time the Submarine Signal Co. began producing the Fathometer for sounding. The transmitter of this equipment consisted of an electromagnet which, when energized, caused a piston to hit against a diaphragm, located in the bottom of a hull and exposed to the sea, which emitted a 1,000-cycle-per-second sound wave. The indicator consisted of a motor-driven disc revolving at constant speed behind a fixed dial containing a circular slot through

[2] Ibid., pp. 6–8.

[3] Ibid., pp. 7–8.

[4] Ibid., p. 2.

[5] Ibid., pp. 2–3.

which a neon bulb fixed to the rotating disc was visible. The dial was calibrated in fathoms based on its angular travel and the speed of sound in water. The zero mark was at 12 o'clock and at this position the impact oscillator was energized and the single signal of short duration was transmitted and at the same instant caused the neon bulb to flash. When the echo of this signal was received by a carbon button-type microphone, also electrically connected to the neon bulb, it caused it to flash again. Meanwhile the disc had travelled a specific angular distance, depending upon the depth of the water which was read directly from the calibrated dial at the instant of its flashing. The impact oscillator signal permitted sound measurement of shallow waters. The fathometer became the standard sounding equipment for naval vessels.[6]

The next important development was by the Hayes group at the Naval Research Laboratory when, in 1929, they produced a listening sonar which replaced the acoustic SC tubes in submarines. This was, in effect, the receiving portion of the echo-ranging sonar and was given the designation JK. Instead of the quartz crystals employed in the echo-ranging apparatus, the JK utilized newly developed rochelle salt crystals which had been found to be more sensitive. The JK transducers were mounted on the top side of all our submarines and increased the listening range to about 5 miles and gave bearings which were accurate within a few degrees. Because of its location this apparatus could be used only when the submarine was submerged. A little later it was modified by the addition of a small transmitter which provided a "ping," similar to that in the echo-ranging apparatus. This was used for underwater communications. A few of the sets were also modified to provide underwater voice communications.[7]

By 1931 the Laboratory had developed the QB echo-ranging sonar for submarines. It was almost identical to the surface vessel sonar except that it also utilized rochelle salt crystals instead of quartz. This equipment was installed in newly constructed submarines in addition to the JK apparatus. It protruded through the bottom of the hull, thus enabling it to be used when the submarine was surfaced.[8]

The Washington Navy Yard was the manufacturer of the quartz-steel echo-ranging equipment and had produced about 20 sets by 1933. At that time it also had approximately 60 of the JK devices under construction. In that year the Submarine Signal Co. was given a contract to provide 30 QB equipments.[9]

At speeds in excess of 5 knots the water noises drowned out target noises and echoes. To reduce the turbulence caused by the movement of the flat-faced tranducers, the laboratory, in collaboration with the Goodrich Tire & Rubber Co., produced a spherical cover, of sound transmitting rubber, about 19 inches in diameter. This permitted increasing the speed to about 10 knots before water noises became excessive. Since the speeds of submerged submarines at that time was less than 10 knots, a satisfactory underwater detection system for their use had been developed.[10]

The invention of a transducer utilizing magnetostriction tubes resulted in the elimination of the quartz and salt crystals commencing in 1934. The magnetostriction tubes are basically small electromagnets 3 inches long and three-eighths of an inch in diameter of hollow nickel alloy tubing, around which is wound a coil of wire. When the magnetic flux is changed the tubes elongate or contact causing a vibration of the attached diaphragm which results in the emission of "pings." Likewise when a sound hits the diaphragm the resultant vibrations cause a change in the

[6] H. J. Fay, "The Submarine Signal Company" (Soundings, December 1945), p. 8.
[7] "Sonar Press Release," op. cit., pp. 2–3.

[8] Ibid.
[9] Ibid.
[10] Ibid.

magnetic flux of the magnetostriction tubes which in turn causes the generation of an electric current which produces sounds in the phones corresponding to those of the source. The Navy equipment was designed by the Bureau of Ships and the Research Laboratory and was manufactured by the Submarine Signal Co. at an approximate annual rate of 14.[11] Following the invention of the magnetostriction transducer, the Submarine Signal Co. adopted it for use in their Fathometers and ceased using the impact oscillator.[12]

OCEANOGRAPHY AND UNDERWATER SOUND

The next several years were devoted to minor improvements of sonar apparatus, developing tactical doctrines and, most important, in the study of the sound-carrying medium, seawater. Shortly after the magnetostriction transducer was incorporated in the sonar equipment, Hayes, the Navy's underwater sound physicist, started a study of the medium. In a cruise from the Chesapeake Bay to Guantanamo Bay, Cuba, the equipment worked perfectly until the ship reached tropical waters. In these waters it picked up strange noises and sometimes failed to receive those which it should. To find the solution to this perplexing situation the Navy contacted the Wood's Hole Oceanographic Institution which dispatched its oceanography vessel, the *Atlantis*, to Guantanamo. The *Atlantis*, commanded by Harvard Prof. C. O. Iselin II, and staffed by trained oceanographers, quickly discovered that the difficulty was caused by varying temperatures of different layers of the ocean's waters. This discovery opened an entire new field for the use of underwater sound and necessitated training submariners in the use of oceanography for concealment and for trailing submarines through the ocean's varied conditions.[13] To provide this training, the Fleet Sonar School was established at San Diego, Calif., and the Radio and Sound School at the Naval Research Laboratory was also expanded to provide this training.[14]

[11] "Sonar," op. cit., p. 3.

[12] Ibid.

RESUMPTION OF BRITISH-AMERICAN EXCHANGE OF UNDERWATER SOUND RESEARCH

With the outbreak of World War II, contracts were made with the Submarine Signal Co. and the Radio Corp. of America to produce echo-ranging sonar to equip all of the U.S. Navy destroyers within 6 months.[15]

When it became evident that we would probably be drawn into the conflict and with our provision of 50 World War I destroyers to the British in payment for leases of bases in their Western Hemisphere territories, there was a resumption of the exchange of scientific knowledge which had been terminated at the close of World War I. It was then discovered that the underwater sound developments in the two countries had been almost parallel. The British had continued the use of quartz-steel transducers in their asdic but had streamlined the dome which housed it. The asdic had the additional advantage over sonar of making a permanent recording of the ranges.[16]

Since the range recorders provide a valuable aid in conducting attacks the Sangamo Electric Co. was provided information concerning the British device and that company quickly developed an American equivalent. The streamlined dome was adopted permitting speeds to be increased to 15 knots.[17]

[13] "Ocean Frontier," Time, vol. LXXIV, no. 1, 6 July 1959; Time Inc., Chicago, Ill., p. 44.

[14] "Sonar," op. cit., p. 4.

[15] Ibid.

[16] Ibid., pp. 4–5.

[17] Ibid., p. 5.

INCREASED SCIENTIFIC EFFORT IN DEVELOPMENT AND USE OF UNDERWATER SOUND EQUIPMENT

Despite the excellent detecting capabilities of the equipment the Nazi submariners, well trained in evasive tactics, were being successful in escaping destruction 95 percent of the time.[18] Studies of the courses lead to the belief that lack of basic scientific knowledge was handicapping the effective use of sound equipment and that, also, there might be some basic error in design. The National Defense Research Committee formed Division VI, under the leadership of Dr. J. T. Tate in April 1941. A laboratory was established at San Diego, Calif., under the University of California Division of War Research. Research groups were established under Columbia University Division of War Research which included a Theoretical Analysis Group, the Underwater Sound Reference Laboratories, and a Sonar Laboratory at New London, Conn. Sponsorship of the oceanographic work of the Wood's Hole Oceanographic Institution was taken over and the assistance of the Scripps Institution of Oceanography was enlisted. Contracts for services of scientists at numerous universities and colleges were made. All possible unused means of underwater detection were investigated without success and the effort was then concentrated on further development of existing sonar techniques. The Royal Navy contributed its entire experience with antisubmarine warfare and its history of scientific investigations of underwater sound.[19]

In September 1941, the U.S. Navy began escorting vessels carrying lend-lease equipment. The Nazis retaliated by torpedoing the U.S.S. *Kearny* and *Rueben James*. Following these sinkings an undeclared war against Nazi submarines began.[20]

Upon our formal entry into the war, 170 destroyers were the only vessels the U.S. Navy had fitted with echo-ranging sonar. The Bureau of Ships began equipping torpedo patrol boats, submarine chasers, motorboats, and yachts with lightweight sonar equipments. Production facilities of the Submarine Signal Co. and the Radio Corp. of America were greatly expanded. Other companies such as the Bell Laboratories, the Western Electric Co., and the Bludworth Co., established additional facilities and began supplying sonar's equipments and accessories.[21]

The Research groups submitted confirmation of the previous supposition that sound is deflected when it passes through regious where a variance of water temperature exists. Bathythermographs were procured and issued both offensive and defensive forces for the purpose of locating thermoclines. The hunter-killer and escort groups used them for the determination of spacing between searching vessels while the submarines used them to assist in evasive tactics.

The Engineering Research Group enlisted the aid of numerous manufacturers and developed three devices which enhanced the utilization of sonar equipment: a "Maintenance of True Bearing" instrument, which keeps the sonar beam on its target during the contacting vessel's maneuvers; an electronic "Bearing Deviation Indicator," which visually indicates when the sonar beam tends to lose contact by being moved away from its target; and a "Reverberation Gain Control," which reduces the heavy reverberations caused by the transmission of pings by the transducer and also reduces undesired echoes from sea growths, shallow water bottoms, tidal currents, wakes and the noises of marine life.[22]

The Theoretical Analysis Group developed improved search and tactical doctrines which were immediately placed into use.[23]

Increased training facilities were established with complete training and coordinating facilities.[24]

[18] Ibid., p. 7.
[19] Ibid., p. 6.
[20] Ibid.
[21] Ibid., p. 8.
[22] Ibid.
[23] Ibid., p. 6.
[24] Ibid., p. 7.

SONAR OPERATIONS IN THE ATLANTIC

The effectiveness of the improved Allied antisubmarine measures was demonstrated in November 1942, when 1,065 assorted Allied vessels made passage from United States and United Kingdom ports to wage the north African invasion, with the loss of only 23 ships to a very determined enemy submarine campaign. Elsewhere however, the measures had not yet begun to show results.

Early in 1943 the German submarines were detected utilizing high-frequency radio for the purpose of concentrating for wolf-pack operations. Information regarding operating areas was provided by shore-based direction finders and these areas were searched by shore based aircraft and by hunter-killer groups augmented by escort carriers. When the submarines submerged they were detected by sonobuoys which had been developed for parachuting from planes. Upon contact the echoes activated small transmitters in the sonobuoy which relayed the sounds to the aircraft which would then guide surface vessels to the locale. By summer 1945 planes from escort carriers, provided accurate information as to enemy submarine operating areas and were guiding the hunter-killer groups to these areas. Although the submarines frequently outnumbered the escorts two to one their effectiveness was being reduced. Improved ordnance was also helping to increase the number destroyed.[25]

In the summer of 1943, Fleet Adm. Ernest J. King, USN, formed the 10th U.S. Fleet with himself as its commander. The nucleus of this fleet was the Antisubmarine Warfare Unit of the Atlantic Fleet. Its assigned tasks consisted of tracking enemy submarines, routing convoys, assigning escorts, and improving uses of weapons and methods of attack. Other activities, with experienced civilian and naval personnel, contributed to the expansion of this fleet. Reports were constantly received by radio and were fed into electronic recording and calculating machines. From the enormous amount of statistical information compiled, improved tactics, doctrines, training, and weapons were evolved. The effectiveness of hunter-killer groups and escorts increased. Towed underwater noise transmitters attracted acoustic homing torpedoes and reduced the number of surface vessels lost. Faster sinking depth charges were developed to reduce the ability of submarines in taking evasive action. Hedgehogs and mousetraps were developed which projected patterns of 30-pound charges, which exploded only by contacting the metal hulls, thereby getting closer to the targets. Additional instruments appended to sonar made it capable of detecting minefields, determining a submarine's depth, providing indication of oncoming torpedoes, of giving more accurate ranges and bearings and to indicate the exact time to fire or launch weapons. Unescorted fast ships were rapidly being fitted with effective hydrophone torpedo detectors which gave them ample time to maneuver, to avoid, and in some instances to attack.[26]

Admiral Doenitz, the German submarine commander, stated that in the fall of 1943

> The boats were ordered to remain on the surface when attacked by aircraft and to cooperate in fighting off the attack. They were then to attack and break up the destroyer screen with acoustic torpedoes, and in the third phase of the battle, attack the convoy now deprived of its protection.

This directive was disastrous to his submarines, for this exposure resulted in a 50-percent loss in effectiveness. In December 1943, he was forced to direct continuous submerged operations. At that time he stated:

> It is essential to victory that we make good our scientific disparity and thereby restore to the U-boat its fighting qualities.

At this time German scientists, who had been drafted into military service, were re-

[25] Ibid., p. 9.

[26] Ibid., p. 10.

leased and aided in the creation of the German Naval Scientific Directional Staff.[27]

During 1943 the tide reached low-water slack. The Allies lost 598 ships, the Axis 263 submarines. During the winter of 1944 the measures instituted by the 10th Fleet combined with Doenitz's directive for submerged operations resulted in the Allies sinking more submarines than the Axis sank ships. Low-water slack was over and the tide had commenced to flood.[28]

When the Allies landed in Normandy, the invasion craft were led by scout boats equipped with small echo-ranging equipment equipped with a recorder which traced the outlines of the beaches and located underwater obstacles which were cleared by demolition teams. The invading forces were provided such intense air cover and such tight radar and sonar screens that not a single vessel was lost to submarines for over 3 weeks. The 7 ships lost following that period cost the Germans 21 submarines.[29]

Just as it appeared that the Allies were winning the Battle of the Atlantic, the Germans developed and equipped their submarines with snorkels which permitted them to recharge their batteries at periscope depth and allowed them to cruise at higher speeds at that depth. Additionally, the exposed portion of the snorkels were covered with a material which reduced the reflection of radar waves. Their new submarines were being constructed with stronger pressure hulls which permitted deeper submergence and offered more resistance to underwater explosions. These actions materially reduced the effectiveness of our air and surface antisubmarine offensive. The Germans took up stalking positions at focal points on convoy routes, lay on the bottom and attacked the convoys with acoustic and looping torpedos. Radio direction finding ceased to be of assistance since the new strategy eliminated radio transmissions. However, these actions came too late to change the course of events. Their strategy reduced their effectiveness and our improved sonar equipment and operating techniques and countermeasures against homing torpedoes kept the tide flooding.[30]

The crucial test came during the Battle of the Bulge, during the winter of 1944–45. An operating average of 40 submarines, plus scores of midget submarines, concentrated in the Channel areas in an endeavor to destroy the shipping which was so essential to our hard-pressed land forces. They could not compete with our hunter-killer groups which in the last 4 months of the war sank 88 submarines and approximately 100 midgets while for the same period Allied losses were 56 vessels.[31]

However, it is generally conceded that continued and constant effort on the part of the Allies would have been required to cope with German improvements. It was Allied opinion that the Germans were constructing submarines which could cruise at submerged speeds which would permit them to outdistance World War II escorts. Only by superiority in science can we hope to keep the peace of the Atlantic.[32] "A military research program may be the price of survival." [33]

SONAR OPERATIONS IN THE PACIFIC

Submarine operations in the Pacific were quite the opposite of those in the Atlantic. The Japanese entered the war with 75 seagoing submarines and a few one-man midgets. In the early days they averaged sinking 10 ships per month in the Far East but this rate soon dropped. On the other hand our submarines commenced ranging the Pacific with great success. Japanese

[27] Ibid., p. 4.

[28] Ibid.

[29] Ibid.

[30] Ibid., pp. 11–12.

[31] Ibid., p. 12.

[32] Ibid., p. 14.

[33] Statement of Secretary of Defense James E. Forrestal.

escorts were initially equipped with hydrophones incapable of tracking our submarines. In 1943 they commenced equipping them with crude echo-ranging equipment with which they had far less success than we had with the same type at the beginning of the war. Additionally, our submariners were, by this time, well versed in evasive tactics and in the use of bathythermographs to find the thermoclines under which they hid, secure from the Japanese detection equipment. Charts were provided of areas in which intense shrimp noises could be utilized to blanket the sounds generated by the submarine. Our submarine echo-ranging sonar had been augmented with an abovehull 3-foot-long, 2-inch-diameter magnetostriction hydrophone which gave excellent directional accuracy on sounds within 10 miles distance in average water conditions. Listening trainers were provided as a sonar attachment to increase proficiency in estimating target speeds by propeller rhythm. Special mine detecting sonar was provided submarines which made submerged excursions into the Yellow Sea and even into Tokyo Harbor.

By the beginning of 1943, the Japanese Army had overextended its operations in the southwest Pacific and was being cut off from its supplies by a rapidly expanding Pacific Fleet. This necessitated the use of their few remaining submarines for supplying isolated outposts and reconnoitering. Thereafter Japanese submarine attacks were purely those made on targets of opportunity. These were usually thwarted by escorts with fatal results to the Japanese who had gained little experience in evading our improved sonar techniques. During 1943 22 enemy submarines were destroyed in the Pacific. In 1944 they possessed 70 seagoing submarines with operational characteristics comparable with those of other countries but which lacked adequate underwater detection equipment. These submarines were pursued relentlessly by our combined surface and air hunter-killer groups and by our own submarines. How unsafe the Pacific was for enemy submarines is indicated by the fact that three U.S. destroyer escorts, in 11 days at the end of May 1943, utilizing sonar and its ancillaries, sank 6 Japanese submarines.

On the other hand, our submarines were annihilating Japanese shipping with some degree of immunity. So terrific were the Japanese losses on the convoy route between Singapore and Tokyo, that they were wont to say that it was possible to walk between the two ports on the periscopes of American submarines. Actually, only a few of our submarines operated in that particular area at any one time.

During the 6 months of the war in 1945 26 Japanese submarines were sunk, and at the time of the surrender only 43 were left and they were largely being held in port. So ineffective were their operations that we were somewhat lulled into a false security. A few days before the end of the war, the U.S.S. *Indianapolis,* steaming southward without using evasive tactics, was torpedoed and lost.

The success of our undersea operations and the lack of success of those of the enemy was the measure of our technological advances against their meager improvements. The disparity was so great that ofttimes a submarine was destroyed before it appeared to have knowledge that it was opposed.

CHAPTER XL

Radio Controlled Aircraft

REVIVED NAVAL INTEREST

As previously related, a project had been established in 1917 for research and experimentation with automatic pilots and radio-controlled aircraft. Although considerable progress had been made by 1925, interest had waned and although the project had not been canceled it lay dormant until 1936.[1]

In early 1935, Commander Aircraft, Battle Force, requested the Chief of Naval Operations to provide high-speed, radio-controlled, armored aircraft targets for bombing practices.[2] A few months later the Plans Division of the Bureau of Aeronautics recommended the development of a radio-controlled aircraft target. This memorandum stated that training of antiaircraft activities must be conducted with greater realism and that further information must be obtained as to the effectiveness of present and projected antiaircraft weapons before further marked improvement in defense could be reasonably expected.[3]

A little later, Commander Battle Force, initiated a request that careful consideration be given to the urgent requirement of the Fleet for radio controlled aerial targets which would provide more realistic training of the fleet's antiaircraft batteries. This was concurred in by the Commander in Chief, U.S. Fleet, without reservation.[4]

[1] Supra, ch. XXIX.

[2] Letter, dated 22 Apr. 1933, commander, aircraft, battle force, to the Chief of Naval Operations.

[3] Memorandum, dated 19 Aug. 1933, Plans Division, Bureau of Aeronautics.

[4] Fleet Training Division, Office of the Chief of Naval Operations, Targets and Rafts Files, 1935–36.

Prior to this time the Royal Navy had developed the "Queen Bee" radio-controlled aerial target. The Chief of Naval Operations, Adm. William H. Standley, USN, had been in England during most of 1935 attending the London Disarmament Conference. While there, he had numerous discussions with high Royal Navy and Air Force officers concerning the valuable training and experience they were gaining through the use of these aerial targets. He returned to Washington in early 1936 thoroughly convinced that realistic aerial targets must be provided the fleet without delay.[5]

As soon as possible after his return Standley discussed the problem with Rear Adm. E. J. King, USN, Chief of the Bureau of Aeronautics. King was in complete agreement both as to the necessity and the immediacy of providing such targets.[6] Following this discussion the Chief of Naval Operations addressed a letter to the Chiefs of the Bureaus of Ordnance, Aeronautics, and Engineering calling their attention to the urgent need of radio-controlled aerial targets and specified the following characteristics for such a plane:

A seaplane with radio-controlled automatic pilot capable of speeds in excess of 100 m.p.h. at an altitude of 10,000 feet.

Desirable that plane be capable of being catapulted under radio control.

Essential that plane be capable of taking off and landing under radio control.

[5] Letter, dated 9 Mar. 1953, Adm. W. H. Standley to Rear Adm. D. S. Fahrney.

[6] Ibid.

In flight, under radio control, it should be capable of straight flight and normal turns, climbs, and glides.

Desirable that it be capable of dives at angles of as great as 45° and of pulling out of such dives.

Radio control of complete range of throttle.

Minimum distance from control station to controlled plane, under favorable conditions must be 10 miles.

Armor not required on targets.

Weight of complete control equipment not to exceed weight of normal crew of similar plane.[7]

Despite Standley's expressed statement concerning the necessity and urgency, the Bureau of Ordnance demurred, stating that the project would overcrowd the facilities of the Naval Proving Ground, Dahlgren, Va.,[8] and seriously interfere with and delay important ordnance developments. The Bureau's reply stated that "the cost of provision and operation of such targets for routine training of antiaircraft batteries would be out of all proportion to the benefits obtainable thereby." [9] The Bureau of Aeronautics expressed a strong interest in the rehabilitation of the project.[10] The reply of the Chief of the Bureau of Engineering expressed more enthusiasm than might be expected from a Bureau little concerned with gunnery. It stated that, although satisfactory results could be obtainable by utilizing full-scale seaplanes, consideration should be given to developing a large stable model aircraft with radio control without using an automatic pilot. The letter ended by expressing the Bureau's keen desire to handle the development of the radio equipment.[11]

REACTIVATION OF THE RADIO-CONTROLLED AIRCRAFT PROJECT

On 1 May 1936, the Chief of Naval Operations directed the Bureaus of Aeronautics and Engineering to proceed with the development of four radio-controlled aircraft. The overall cognizance of the project was assigned to the Bureau of Aeronautics and both bureaus were requested to give the project a high priority.[12]

By 1 July, the Bureau of Aeronautics completed its procedure plans. These called for heading the project with an aviator qualified to study the aerodynamic requirements, select and supervise the installation of the stabilization equipment, and direct necessary redesign.[13] The billet was established and Lt. Comdr. D. S. Fahrney, USN, was ordered as Officer in Charge of the Radio-controlled Aircraft Project on 20 July.

After a study of previous work in radio control, Fahrney submitted his plans on 6 August.[14] A landplane of high inherent stability would be selected and, in accordance with the recommendation of the Bureau of Engineering, the automatic pilot would not be used unless later found necessary. Work on the project would be conducted at the Naval Aircraft Factory, Philadelphia, Pa. The radio equipment would be developed by the Radio Division, Naval Research Laboratory, under the supervision of Dr. A. Hoyt Taylor. These plans were endorsed by the Chiefs of the Bureaus of Aeronautics and Engineering and were approved by the Chief of Naval Operations.[15]

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[7] Letter, dated 23 Mar. 1936, Chief of Naval Operations to the Chiefs of the Bureaus of Ordnance, Aeronautics, and Engineering.

[8] The earlier radio-control project had never been canceled and the tests and experimentation had been conducted at this station.

[9] Letter, dated 28 Mar. 1936, Chief of the Bureau of Ordnance to the Chief of Naval Operations.

[10] Letter, dated 15 Apr. 1936, Chief of the Bureau of Aeronautics to the Chief of Naval Operations.

[11] Letter, dated 24 Apr. 1936, Chief of the Bureau of Engineering to the Chief of Naval Operations.

[12] Letter, dated 1 May 1936, Chief of Naval Operations to the Chiefs of the Bureaus of Aeronautics and Engineering.

[13] Letter, dated 1 July 1936, Chief of the Bureau of Aeronautics to the Chiefs of the Bureaus of Ordnance, Engınereing, and Navigation.

[14] Memorandum, dated 6 Aug. 1936, Officer in Charge, Radio-controlled Aircraft Project, to the Chief of the Bureau of Aeronautics.

[15] Letter, dated 9 Sept. 1936, Chief of Naval Operations to the Chiefs of the Bureaus of Aeronautics and Engineering.

Mr. William Wait, Jr., an aeronautical engineer, was assigned as an assistant to Fahrney in September 1936. The Naval Research Laboratory assigned two radio engineers, Messrs. E. L. Luke and J. C. Link, to the project plus the part-time services of Messrs. L. C. Young, M. H. Schrenk, and H. F. Hastings. The Naval Aircraft Factory assigned the following petty officers: F. Wallace, C. E. Herzog, L. B. McKeon, H. D. Schultz, and H. E. Foster. Wallace was a chief aviation pilot. In January 1913, Mr. George A. Spangenberg, a junior engineer, was added, and in April Radio Electrician S. E. Herbst, USN, an aviator, reported for duty with the project.[16]

NAVY DEVELOPMENT OF THE DRONE

Four Stearman Hammond Y planes, fitted with tricycle landing gear, were ordered and one training plane built by the New Standard Aircraft Corp. was assigned the project. Later, the delayed delivery of the Stearman Hammond Y planes necessitated the assignment of two N2C-2 training planes.[17]

At the time of the resumption of work on this project, radio communications were vastly superior to those existing in 1925. High-frequency equipment had become available and highly dependable improved standard equipments were available such as the GP-2 transmitter and its associated RV-3 receiver. Both of these were selected as components. The major problem involved in the radio-control equipment was the development of a means of modulating the carrier wave of the transmitter and of demodulating this at the receiver. In the earlier experiments a vibrating reed was forced to vibrate between magnetic poles, thus providing a steady tone which was then imposed on the carrier wave. This method was again used but was improved by Naval Research Laboratory personnel. The design of the circuits, selection of components, fabrication, and tests were carried out under the direction of Schrenk, aided by the previously mentioned Laboratory personnel.[18]

The equipment, as designed, provided 12 distinct radio channels. Two of these were allocated to each control, aileron, elevator, and throttle, and one for intermittent signals. This left three spare channels which could be assigned to any of the above functions as required. The automatic pilot was to be used. It was planned to secure the rudder in the neutral position and make all turns with the ailerons. If this proved impracticable under test, then it was contemplated that the rudder and aileron controls would be linked together.[19]

In his semiannual report for the last 6 months of 1936, the Officer in Charge of the project initiated the term "drone" as descriptive of the radio-controlled aerial targets. That designation has persisted and will be used hereinafter.[20]

In order to test the design of the system and the selection of components, a laboratory "drone" was fabricated at the Naval Research Laboratory. This was fitted with a working model of the complete radio-control system. The control station was set up in one location and the equipment for the drone was placed a few hundred yards away. Signals transmitted from the control station actuated movements of the simulated control surfaces of the laboratory drone. Many tests, which aided in the improvement of both the radio and mechanical components, were carried out prior to February 1937. On 17 February this laboratory drone was controlled by a TU-2 control plane from a distance of 25 miles.[21]

[16] Naval Aircraft Factory controls files.

[17] Letter, dated 12 Nov. 1936, Officer in Charge, Radio-control Project, to the Chief of the Bureau of Aeronautics.

[18] Letter, dated 9 Nov. 1936, Director, Naval Research Laboratory, to the Chief of the Bureau of Engineering.

[19] Semiannual report, December 1936, Officer in Charge, Radio-control Project.

[20] Ibid.

[21] Letter, dated 8 Apr. 1937, Officer in Charge of Drone Project.

Illustrative of the support the project was receiving, the above test was witnessed by the Assistant Secretary of the Navy, the Honorable Charles Edison, and many high-ranking naval officials.[22]

By the middle of March 1937, one complete unit was ready for installation in the TG–2 control plane and the NT drone. The latter had been modified for the installation of the hydraulic and radio-control apparatus. After installation, tests were run with both planes on the ground and then with the control plane in the air and the drone on the ground.

On the afternoon of 23 March, a test with both planes in the air was conducted. The results of this are quoted from Fahrney's report:

". . . the planes took the air at about 1300 with Wallace in the NT drone as a safety pilot and Fahrney as controlling pilot in the front cockpit of the TG–2. At 3000 feet the circuits were tested and found to be in working order. The drone pilot was ordered to throw in the gear. Shortly therafter, there ensued the most astonishing evolutions which could only be ascribed to a drunken pilot. The drone went into wild gyrations to the right and to the left with plenty of climbs and dives mixed in to give Wallace a most harrying ride. After a few moments of anxious concern it developed that the controls governing climb and dive were satisfactory, but the aileron controls were decidedly 'hay wire'. The drone pilot was requested to throw out the gear, when the right turn control was operated, the plane went immediately into a left turn and the more the right turn signal was given by radio, the more tight the left turn became. The obvious fact that the controls were crossed was not at first apparent because the safety pilot threw out the gear and brought the plane back to level flight after each unusual maneuver."

The planes were taken up again and the test of radio control proved that it was adequate for all normal maneuvers.[23]

Following this, a neutralizing mechanism which could be actuated by radio was developed and installed, and this, combined with a modified turn-and-bank instrument, provided a fair automatic pilot for level and straight flights of short distance.[24] However, the drone would still gradually wander offcourse. The instrument section of the Naval Aircraft Factory placed electric contracts, controlled by photoelectric cells, in a Sperry directional gyro instrument. This unit could be controlled by radio so that when the drone was on a selected course the instrument could be placed into use and could keep it on course.

Delay in delivery of the Stearman Hammond Y planes prevented any attempt to make a pilotless flight since it was considered unsafe to attempt a landing under radio control except with drones fitted with tricycle landing gear. When, in early August 1937, these planes were still not delivered, an N2C–2 plane, reconfigured to take the control equipment and refitted with tricycle landing gear, was assigned. The fitting of this plane was completed on 7 October, after which it was repeatedly tested under all possible conditions. At this time a second TG–2 plane was also assigned for use as a second aerial control station.

On the morning of 15 November 1937, a complete check of all equipment was made and four perfect takeoffs and landings were effected under radio control with a safety pilot in the N2C–2 drone. At about 1330, the same day, the TG–2 control plane took off with Wallace in the radio-control cockpit. When the control plane was on station, Fahrney, at the ground control station, opened the pilotless drone's throttle by radio and the plane made a normal takeoff. When it reached an altitude of 200 feet the control was shifted to the TG–2 which controlled it through simple maneuvers for about 10 minutes, after which it lined it up for a landing

[22] It is most probable that had the earlier experiments in radio control created interest among the higher responsible officials it would have been carried through to completion at that time. Had that been done the experience gained in a decade would have placed the United States far ahead in guided-missile development.

[23] Letter dated 8 Apr. 1937, Officer in Charge, Drone Project.

[24] Letter, dated 00 Mar. 1937, Officer in Charge, Drone Project.

approach. The control was shifted back to the ground control station. Some difficulty was experienced; the plane made a hard landing, carried away the front wheel, and skidded along on its nose for about 40 feet while the rear wheels slowly crumpled.[25]

Meanwhile, delivery of the two Stearman Hammond Y (SH–1) planes had been made and an additional N2C–2 was assigned. Efforts were concentrated on fitting one of the JH–1 planes as a drone. By 23 December this had been accomplished and the plane had been tested numerous times with a safety pilot. On that date a pilotless flight, utilizing the same procedure used in the previous ill-fated one with the N2C–2 drone, was successfully completed.[26]

Following this flight, flying was discontinued for the winter. The following months were utilized in perfecting the existent equipment, designing and testing new components, and in fitting four drones for operation with the Fleet.[27] The radio control equipment was functioning so reliably that Schrenk turned his attention to the development of a repeat back system which would enable the remote control station to see instantly the conditions existent in the drone. This was accomplished but in practice was found unnecessary under normal conditions, since observation by eye and experience gained in controlling the drones proved sufficient.[28]

Flying operations were resumed on 18 April 1938. By the 27th of that month, sufficient test and practice flights had been made to warrant another attempt at a pilotless one. This was accomplished with an N2C–2 drone making three pilotless flights under the control of various pilots from both ground and air control stations.[29]

[25] Letter, dated 14 Dec. 1937, Officer in Charge, Drone Project.

[26] Semiannual report, dated 4 Jan. 1938, Officer in Charge, Drone Project.

[27] Letter, dated 16 Mar. 1938, Officer in Charge Drone Project.

[28] Letter, dated 2 Feb. 1938, Naval Research Laboratory to the Bureau of Engineering.

[29] Report, datted 13 May 1938, Officer in Charge Drone Project.

USE OF DRONES AS FLEET ANTIAIRCRAFT TARGETS

Tests were continued throughout early May with such success that a unit was established to provide aerial targets for the fleet. On 1 June, movement of equipment and personnel to San Diego, Calif., was commenced. It was assigned to the Fleet Utility Wing, and preparations for utilizing drones as aerial targets were started.[30]

On 24 August 1938, a drone was first used by the Navy as an aerial target for the U.S.S. *Ranger*. The practice simulated firing at a horizontal bomber which had passed over the ship. For the first time in this country, a maneuvered target was being fired upon by a surface antiaircraft battery. The personnel of the antiaircraft battery were exceptionally well trained, but they failed to score a single hit on either of two runs by a drone over the ship while firing between 4,000 and 6,200 yards slant range.[31]

During the second run the control plane opened out from the drone from 1 to 2 miles upon request of the U.S.S. *Ranger*. Upon conclusion of firing, the smoke from the shrapnel bursts obscured the drone from the controlling aircraft so that it was not possible to determine its altitude. In endeavoring to have the drone close, the remote pilot put in a tight 180° turn, from which it went into a dive. Control was shifted to Fahrney in the standby controlling aircraft. At that time the drone was directly below Fahrney and continuing in its dive. It answered the up-elevator signal, made a full loop, then fell into a steep spiral dive from which it did not recover, and crashed into the sea.[32] "Operation successful—patient died." [33]

[30] Memorandum, dated 2 May 1938, Officer in Charge Drone Project to Plans Division, Bureau of Aeronautics.

[31] Report, dated 29 Aug. 1938, Commanding Officer, U.S.S. *Ranger*.

[32] Report of loss of drone, dated 25 Aug. 1938.

[33] Route slip comment, dated 29 Aug. 1938, by Comdr. A. C. Davis on U.S.S. *Ranger* report of practice.

The next practice utilizing a drone as an aerial target was held on the 14th of September, with one simulating a dive-bombing attack against the U.S.S. *Utah*. The gunners were successful in bringing the target down by scoring a hit on the second salvo.[34]

The following year the use of drones as aerial targets was greatly increased and eventually became routine. The inadequacy of our antiaircraft defense against a maneuvered target was revealed and resulted in accelerating the improvement of our fire-control equipment. Fortunately, two electronic devices became available at about this time to aid in this improvement—radar and the proximity fuze.

NAVY DEVELOPMENT OF TELEMETERING FOR AIRCRAFT

It was only natural that the successful development of the drone would revive the World War I project of the flying bomb. Shortly after the aircraft radio-control program was reactivated, Fahrney recommended that the project be expanded to include guiding an aerial torpedo to a target and investigating the use of radio control in testing new aircraft.[35]

The Chief of the Bureau of Aeronautics, on 27 October 1937, directed the Manager, Naval Aircraft Factory, to make a detailed study of the possibility of using radio control for testing new aircraft.[36] Following completion of this study the Aircraft Factory outlined the following as necessary development for such a project:

A means of transmission by radio of the information indicated on the aircraft's flight instruments;

Means by which the synchronized records of the control positions might be obtained; and

Means of obtaining records of the structural test instruments by radio and of recording them.[37]

After considerable time-consuming discussions between the various divisions of the Bureau, the Naval Aircraft Factory was directed to proceed with the project with major emphasis to be placed on a television repeat-back system.[38]

Early in 1938 the possibility of using television equipment in a repeat-back system was discussed with engineers of the Radio Corp. of America. Following this, the Naval Aircraft Factory recommended that a television equipment be purchased for tests. This was not approved until October 1939 and was not obtained until late February 1940. Tests with it were carried out the remainder of that year.

In January 1941, negotiations were completed with the Radio Corp. for installing one set of their latest type of television in an experimental twin-engine observation and utility plane fitted with tricycle landing gear. The Chief of the Bureau of Aeronautics, on 17 January 1941, outlined the tests desired, placing great emphasis on the televising of instruments to permit control of a drone beyond visual range, to transmit structural test data to a ground station, and the televising of the view ahead of an assault drone headed toward a target.[39]

By 17 February 1941, tests of this equipment gave promise of provision of usable picture informations from a plane in flight distant 20 to 30 miles from a ground receiving station. By June of the same year, the tests had progressed to the point where the television transmitter was providing pictures of sufficient quality on the receiver in another plane that the pilot in the latter

[34] Report, Commanding Officer, U.S.S. *Utah*. Fleet Training File (Targets and Rafts), 1935–39.

[35] Letter, dated 24 Aug. 1936, Chief of the Bureau of Aeronautics to the Chief of Naval Operations, file Aer-E-17-EP, F-31-1 (43).

[36] Letter, dated 27 Oct. 1937, Chief of the Bureau of Aeronautics to Manager, Naval Aircraft Factory, files Aer-F-32.

[37] Letter, dated 5 Jan. 1938, Manager, Naval Aircraft Factory, to the Chief of the Bureau of Aeronautics, file NAF-F32.

[38] Letter, dated 14 Oct. 1939, Chief of the Bureau of Aeronautics to Manager, Naval Aircraft Factory, file Aer-F31-1 (43).

[39] Letter, dated 17 Jan. 1941, Chief of the Bureau of Aeronautics to Manager, Naval Aircraft Factory, file Aer F31-1 (43).

could direct the pilot of the transmitting plane to alter course as pass directly over a selected target.[40] Meanwhile, the Radio Corp. developed a small television camera and transmitter which, with its power supply, weighed only 70 pounds. This equipment proved successful in supplying satisfactory information for telemetering purposes.

NAVY DEVELOPMENT OF GUIDED MISSILES PRIOR TO WORLD WAR II

To distinguish the development of guided missiles from that of aerial torpedoes and flying bombs of World War I vintage, the following definition of the former was evolved prior to 1942:

> A guided missile in an unmanned vehicle travelling above the surface of the earth which is guided from the launching point to the target by command signals outside the vehicle or by sensing equipment within the vehicle or by a combination of these systems.

In all truthfulness, the Navy was slow to see the possibilities of guided missiles. The first known proposal of these weapons was made to naval officials in 1934 by Dr. V. K. Zworykin, pioneer developer of television for the Radio Corp. of America. The Navy Department concluded that it was unsuited as a naval weapon because of its weight, lack of target penetration, and complexity.

Again, in 1937, Zworykin made strong representation to the Navy Department in support of the development of guided missiles. A board of officers was convened to study his proposals, and on 27 February 1937, reported unfavorably upon them. In commenting upon the Board's report the Chief of Naval Operations stated:

> . . . am satisfied that, at least for the present, the situation does not justify any expenditure of funds for experimental purposes in this field of endeavor.[41]

This decision prevailed until March 1940 at which time, with the international situation deteriorated and a possibility that we might be drawn into the conflict, the Chief of the Bureau of Aeronautics directed that one of the TG-2 torpedo planes which had been employed as a drone control be fitted as a radio controlled plane which could be flown at a set altitude, just clear of the water. Meanwhile, the Commander-in-Chief, U.S. Fleet directed the commander of his drone unit to conduct tests to determine the practicability of the use of radio controlled torpedoes. These tests indicated that a drone could be flown into a target consistently by a control operator flying one and one-half miles astern of the drone.

In commenting on these tests, the Chief of the Bureau of Aeronautics, on 30 October 1940, advised the Chief of Naval Operations that a number of projects were being examined which should lead to the development of a guided missile. The most important of these were:

> An interference-free radio-control system (Naval Research Laboratory);
>
> A radar altimeter (Naval Aircraft Factory and the Western Electric Co.);
>
> A radio-controlled automatic pilot (Naval Aircraft Factory); and
>
> A television guidance system (the Radio Corp. of America and the Naval Aircraft Factory).[42]

In a report several months later Fahrney stated:

> As far as can be determined the Navy has outstripped all countries in the development of radio control for aircraft and it now appears logical that the Navy should develop the first radio controlled aerial torpedo.[43]

In a letter, dated 17 January 1941, the Chief of the Bureau of Aeronautics stated:

> The Bureau is particularly desirous that the technique of operating offensive torpedo carrying radio controlled aircraft be pushed to a conclusion and that sufficient flight tests of aircraft television be

[40] Letter, dated 4 June 1941, Manager, Naval Aircraft Factory, to the Chief of the Bureau of Aeronautics, file NAF-F32.

[41] Memorandum, dated 13 Oct. 1939, J. M. Lane to the Chief of the Bureau of Aeronautics, file F31–1 (43).

[42] Letter, dated 30 Oct. 1940, Chief of the Bureau of Aeronautics to the Chief of Naval Operations, file F32 (Controls).

[43] Memorandum, dated 16 Dec. 1940, Fahrney to the Chiefs of the Bureaus of Engineering and Aeronautics, file F31–1 (43).

carried out to permit recommendations for useful application for naval work.[44]

Following this the Chief of the Bureau of Ordnance provided that Bureau's first indication of support of the program. In a letter to the Chief of Naval Operations he suggested that all-out efforts be made to develop the missile.[45]

In a report to the Chief of Naval Operations, on 18 April 1941, the Chief of the Bureau of Aeronautics advised that progress in the program was satisfactory, and that radar was being developed to replace television as a guidance system in order to allow operations under all conditions of visibility.[46]

Prior to this time, it was discovered that the radar altimeter which had been developed by the Western Electric Co. was too bulky and heavy for use in the missile. By 29 January 1941, the Radio Corp. of America had succeeded in the development of a satisfactory one which gave the required excellent low-altitude performance.

During August 1941, tests in which depth charges and torpedoes were dropped from the radio-controlled plane were conducted. The Manager of the Naval Aircraft Factory, Webster, in reporting these stated:

Approximately fifty simulated torpedo attack runs were made with the drone under radio control, using the television equipment to sight and effect a collision track on the target. All runs except three were satisfactory. In addition the drone was maintained under continuous radio control, television guided, for a period of forty minutes (during which time the control pilot was not able to see the drone), made runs on a target, returned the drone to the initial point and repeated the runs. The maximum distance that a clear picture was obtained (television) was six miles.[47]

On 8 October 1941, Webster reported that the radio-controlled aerial weapon was almost ready for service testing and inclusion in naval warfare planning. Only the altimeter control was lacking, and the Radio Corp. of America equipment would possibly meet the requirements. His report indicated that a plane could be visually directed into collision with a target or into proper position for torpedo launching by a control plane 4 miles distant. With the utilization of television guidance, the control plane could be at a much greater distance. He also indicated that an all-weather radar guidance system being developed by the Naval Research Laboratory and the National Defense Research Council showed excellent promise.[48] This report was forwarded to the Chief of Naval Operations, who, on 28 October, stated:

Progress in the assault drone program is of great interest to the Chief of Naval Operations and to the service at large. It is considered that exploration are being conducted along lines dictated by possible practical service applications.[49]

On 24 October a conference was held between representatives of the Bureaus of Ordnance and Aeronautics for the purpose of planning future tests for proving the feasibility of the new weapon. Following this conference, the Chief of the Bureau of Aeronautics addressed a letter to the Chief of Naval Operations outlining the proposed tests. In this letter he suggested that 100 obsolete TBD planes be assigned the program and that as SB2D and SB2C planes became obsolete that they also be assigned. Additionally, he stated that studies were being conducted to determine the design of special aircraft for the project in both low- and high-performance categories.[50] It was

[44] Letter, dated 17 Jan. 1941, Chief of the Bureau of Aeronautics to the Manager, Naval Aircraft, file F31–1 (43).

[45] Letter, dated 15 Apr. 1941, Chief of the Bureau of Ordnance to the Chief of Naval Operations, file F31–1 (43).

[46] Letter, dated 18 Apr. 1941, Chief of the Bureau of Aeronautics to the Chief of Naval Operations, file F–32 (C1693).

[47] Letter, dated 22 Aug. 1941, Manager, Naval Aircraft Factory, to the Chief of the Bureau of Aeronautics, file F31–1 (43) (4465).

[48] Letter, dated 8 Oct. 1941, Manager, Naval Aircraft Factory, to Chief of the Bureau of Aeronautics, file F32 (36249).

[49] Letter, dated 28 Oct. 1941, Chief of Naval Operations to Chief of the Bureau of Aeronautics, file F32.

[50] Letter, dated 4 Nov. 1941, Chief of the Bureau of Aeronautics to the Chief of Naval Operations, file F32.

imperative that these special expendable assault aircraft be developed in such a manner that they could be manufactured in quantities by industries not connected with the aircraft industry, because Admiral Towers was emphatic in his decision that the overburdened industry not be further burdened with a weapon unproven in combat.

The Japanese attack of 7 December 1941 necessitated the use of every available plane for combat or training; thus, the obsolete planes did not become available to the program. The special assault aircraft was therefore given high priority for early development.

THE AERIAL RAM PROJECT

In March 1941, the Chief of Naval Operations directed the establishement of a drone squadron on the east coast to provide services for the Atlantic Fleet. This was organized as VJ–5 under Lt. R. F. Jones, USN, who had commanded the drone squadron on the west coast. It was based at Cape May, N.J.

Jones had become interested in guided missiles following the radio-controlled torpedo tests he had conducted at the direction of the Commander in Chief, U.S. Fleet. As soon as his squadron was established at Cape May, he began looking for a development assignment in this field. On 9 July 1941 he submitted a plan for the development of a radio-controlled fighter plane to be used as an aerial ram. He stated that this ram could be developed, tested, and personnel trained in its operations in 4 months.[51]

There were strong dissents to this proposal by the subordinate officers in the Bureau of Aeronautics based on the premise that an operational unit should not be utilized for research and development purposes. Nevertheless, the Chief of the Bureau forwarded it to the Chief of Naval Operations, recommending that Jones' proposal be approved. On 8 October 1941, the Chief of Naval Operations directed that the development of the ram proceed under the direction of Utility Squadron 5. This directive was broad and stated as a mission:

> To develop, test, and operate radio-controlled offensive weapons and to train personnel in their use.

The directive also approved the squadron's request for aircraft, personnel, and electronic equipment.[52]

This directive established duplication of effort by the Naval Aircraft Factory and Utility Squadron 5. In all probability this was done to hasten work on guided missiles by the introduction of competitive spirit and to aid in the elimination of dogmatic ideas. The project of Utility Squadron 5 was designated as Project Dog and that of the Aircraft Factory as Project Fox.

Dissension quickly arose between the personnel of the two projects over the type of control to be utilized in guided missions. The Project Dog recommended the utilization of all electric photocell pilots while those of Project Fox maintained that the "air pickoff type," long used in drones, was preferable.

Project Dog quickly became hampered by operational requirements. Since Jones had promised an operational device within 4 months and since the Chief of the Bureau of Aeronautics was keenly interested in remote control of the latest type of fighter aircraft, he, on 30 April 1942 requested the Chief of Naval Operations to direct Utility Squadron 5 to make a progress report.[53]

Jones submitted the report on 20 May, listing the following successes in the development of new equipment or improvement of existing equipments, directional stabilizer, automatic band control and control

[51] Letter, dated 9 July 1941, Commander, Utility Squadron 5, to the Chief of the Bureau of Aeronautics, file VJ-5/F41–10 (5–1–41).

[52] Letter, dated 8 Oct. 1941, the Chief of Naval Operations to the Commander in Chief, U. S. Atlantic Fleet, file CNo F32.

[53] Letter, dated 30 Apr. 1942, Chief of the Bureau of Aeronautics to the Vice Chief of Naval Operations, file Aer F31—1 (43) (5141).

box, pulse control, and automatic altitude control. He stated that, in his opinion, they were satisfactory for guided-missile controls. He closed his report stating that demands for target drone services, lack of shop facilities and test equipment, and lack of laboratory facilities caused delays and lack of accomplishment.[54]

As a result of Jones' report, Project Dog was divorced from Utility Squadron 5 and transferred to Utility Squadron 6, which was especially established for this purpose. Despite this, the next monthly report recommended the transfer of Project Dog to the Naval Aircraft Factory.[55] This was done, but little work was accomplished in this air-to-air category weapon at the time. Later it was briefly exploited as a *Gorgon* missile. However, the project did accelerate the work of Project Fox.

WORLD WAR II DEVELOPMENT OF GUIDED MISSILES

On 15 December 1941, Captain Oscar Smith, USN, unaware of the assault drone program, transmitted a letter to the Chief of Naval Operations concerning the use of radio-controlled aircraft for offensive purposes. He stated:

> We need no suicide squad to dive torpedo laden airplanes into the sides of enemy ships. Let a simple type of radio control be placed on a plane, and we have a suicide pilot who will not falter, but will obey all the orders of the controlling plane, and will not hesitate to fly within 100 yards before dropping his torpedo.[56]

Smith's letter was circulated for comment. The Chief of the Bureau of Aeronautics outlined the work being done on the assault drone program and the successes obtained.[57] By early February, having had no reply, Smith addressed a second letter to the Chief of Naval Operations requesting that he be apprised of the action being taken on his original letter. In this letter he requested that he be placed in charge of the weapon project, stating:

> My request for supervision over the development should not be rejected because I am not an aviator. I can bring more experience and as much common sense to the project as any aviator, and an equal or greater enthusiasm. There are few aviators who flew before my first flight in 1912, and none who has had greater interest in the adaptation of aviation to naval warfare.[58]

Within the same month Smith was assigned duty as the Director of the Plans Division in the Office of the Chief of Naval Operations. One of his first acts was to personally investigate the work being done on the assault drone program. Following this he addressed another letter to the Chief of Naval Operations describing the tests he had witnessed, which had impressed him greatly. He added:

> In my opinion the urgency of our situation and the possibilities of this weapon are such as to make it essential the regular peacetime developments be shortened and the drone be hurried along for actual use.[59]

The Vice Chief of Naval Operations, Vice Adm. F. J. Horne, USN, was so impressed by Smith's report that he directed him to arrange tests which would show the missile's ability to accurately hit moving targets. In compliance with this, Smith prepared a letter, for signature of the Chief of Naval Operations, addressed to the Chiefs of the Bureaus of Aeronautics, Ships, and Ordnance, directing them to proceed forthwith to adapt the drone for warfare. It was requested that the Chiefs of the three con-

[54] Letter, dated 20 May 1942, Commander, VJ—5, to Commander in Chief, Atlantic Fleet, file VJ—5 F31—1 (43).

[55] Letter, dated 19 June 1942, Commander, VJ—6, to Commander in Chief, Atlantic Fleet, file VJ—6 F31—1 (43) (S—3—42).

[56] Letter, dated 15 Dec. 1941, Oscar Smith to the Chief of Naval Operations, file F31—1 (43).

[57] Letter, dated 7 Jan. 1942, Chief of the Bureau of Aeronautics to the Chief of Naval Operations, file Aer—M—15.

[58] Letter, dated 7 Feb. 1942, Oscar Smith to the Chief of Naval Operations, file F42—1.

[59] Letter, dated 9 Mar. 1942, Oscar Smith to the Chief of Naval Operations, file F42—1.

Means of dropping or housing landing gear after drone became airborne;

cerned bureaus appoint representatives to witness and report on tests to be conducted to determine the necessary characteristics for assault drones and control planes and to consider the tactical employment of the new weapon.

On 14 March 1942, the Chief of Naval Operations signed this letter directing that drone attack tests be carried out. Commander, Service Force, Atlantic Fleet, was ordered to provide the necessary services, including the photographing of the tests. Operational tests to prove the missile's capabilities consisted of a drone torpedo attack using television direction, against a maneuvering ship; a drone crashing into a moving battle raft, using both visual and television direction.

The tests were carried out during April and were witnessed by the board established for that purpose. The board's report contained statements of the assault drone's proven capabilities, additional capabilities required to make it a practical and efficient weapon, and listed additional equipments necessary to provide it with essential ability and adaptability for combat usage. Proven capabilities were that the plane could be taken into the air under radio control, guided to the target area visually, and then directed against a target seen on a television screen with remarkable accuracy. The required additional capabilities, most of them involving electronic control methods, included:

Means of dropping or housing landing gear after drone became airborne;

Selection of several, preferably ten, preset altitudes for flying drone under radio altimeter control;

Controlled air explosion for purpose of blasting upper decks;

Control plane knowledge of drone's position regardless of visibility conditions from takeoff to target;

Bomb or torpedo dropping automatically when proper position reached; and

Automatic target seeking;

The last three of these required further development, and action to bring this about was immediately initiated by Smith.

On 23 March, the Bureau of Aeronautics was directed to procure 200 expendable assault drones. One week later, the Naval Aircraft Factory was directed to manufacture 100 plywood assault drones, designated TDN–1, and to contract with a commercial firm for another 100 to be delivered prior to 1 November 1942. The contract was made with the Interstate Aircraft & Engineering Co. and these drones were given the designation TDR–1. Since the design was limited to engines and materials available outside the established aircraft industry, these planes possessed low-performance characteristics.

On 1 August 1941, the Naval Research Laboratory, at the request of the Chief of the Bureau of Aeronautics, had commenced the development of a drone radar and drone radar repeat-back system. Concurrently, the National Defense Research Council commenced the development of a drone 3-centimeter radar recognition system.[60] In April of the next year he followed this with another letter to Laboratory summing up the entire program, making reference to previous correspondence concerning the control of a number of drones by a single control plane by use of radar, the use of pulse radar to free the radio control of enemy or other interferences, and the use of radar for homing drones. Tests conducted at the Naval Aircraft Factory with 3-centimeter radar, installed in a dome under the fuselage of a utility plane, permitting a full sweep and making it possible to control several drones and keep track of a target at the same time, were described. The Chief of the Bureau stated that when drones could be fitted with interrogation, friend or foe, radar (ASB515), radar pulse control equipment, and radar homing, operations by radar could be carried out. The last four requirements were being developed by the Laboratory. The letter was concluded with the statement that the 200 assault drones

[60] Letter, dated 1 Aug. 1941, Chief of the Bureau of Aeronautics to Naval Research Laboratory, file F31–1 (43) (290).

were being configured for fitting in both television and radar controls.[61]

The program was again expanded, by a letter dated 6 May 1942, when the Chief of the Bureau directed the Aircraft Factory to make a study of controlling assault drones from surface vessels and submarines using radio and 3- or 10-centimeter radar.[62]

In early May 1942, motion pictures of the tests held in Narragansett and Chesapeake Bays were shown Admiral King, Vice Admiral Stone, the Chiefs of bureaus, and others. Oral presentations concerning the program were made by Smith and Fahrney. Following this, Admiral King directed Admiral Horne to prepare a plan and program for expediting the development and employment of drones as guided missiles in combat. The plan was submitted within a few days and, as approved by Admiral King, directed:

> The development of a service weapon from the assault drone; and
>
> The readying of the weapon for combat use in quantity at the earliest practicable date.

It will be recalled that this decision was made at a time when our situation was precarious. We were losing the Battle of the Atlantic; the Battle of Midway had not occurred; and we were barely maintaining the toehold we had established at Guadalcanal.

On 22 May, the Vice Chief of Naval Operations appointed Smith as his direct representative for forwarding the project and in reaching adjustments to hasten completion of the program on a practical basis. At the same time he directed that the 200-assault-drone program previously authorized be increased to 1,000.[63]

It was felt that the first use of guided missiles should be widespread and in sufficient quantity to catch the enemy unprepared and that there should be sufficient opportunity to make repeated attacks before effective countermeasures could be developed.[64]

In a letter forwarded on 2 June, Admiral Horne stated that a minimum delivery rate of 300 assault drones per month would be necessary and that 500 per month would be preferable.[65] Earlier correspondence had specified the employment of 18 squadrons in the initial attack, using 162 control planes. This required 500 ready drones with an equal number in reserve. In a letter dated 22 May, the Vice Chief of Naval Operations established "Project Option" and stated:

> The need for this weapon is so urgent that the chiefs of the Bureaus addressed are requested to proceed with the indicated development and production as far as possible—their comment on an irreconcilable conflicts found to exist with their programs.[66]

Analyzing the problem, the Bureau of Aeronautics calculated that 10,000 naval personnel, including 1,300 aviators, would be required. In order to achieve the required production rate it would be necessary to make initial contracts for 5,000 assault drones. The total cost was estimated to be about $235 million. With the training program lagging behind planned objectives and with the aircraft industry already heavily overloaded, Admiral Towers, on 29 June, requested that the program be reduced to 500 assault drones.[67]

At this time, Smith was relieved of his duties as Director of Plans, Office of the Chief of Naval Operations, and appointed head of a Guided Missiles Committee convened to inspect every possible guided-missile project. Upon completing his inspec-

[61] Letter, dated 21 Apr. 1942, Chief of the Bureau of Aeronautics to the Naval Research Laboratory, file F31–1 (43).

[62] Letter, dated 6 May 1942, Chief of the Bureau of Aeronautics to Manager, Naval Aircraft Factory, file Aer F31–1 (43).

[63] Letter, dated 22 May 1942, Vice Chief of Naval Operations to the Chief of the Bureau of Aeronautics, file F31–(43) (040212).

[64] Statement, Commodore Oscar Smith, USN.

[65] Letter, dated 2 June 1942, Vice Chief of Naval Operations to the Chief of the Bureau of Aeronautics, file F31–1 (43).

[66] Letter, dated 22 May 1942, Vice Chief of Naval Operations to Chiefs of the Bureaus of Ordnance, Ships, and Aeronautics, file F31–1 (43).

[67] Letter, dated 29 June 1942, Chief of the Bureau of Aeronautics to the Vice Chief of Naval Operations, file F31–1 (43) (Aer–PL–ES).

tions Smith reported to King and Horne that in his opinion there was no project other than the Navys' which could be developed in time to make a major contribution toward winning the war.

The Chief of Naval Operations accepted Towers' recommendation that the program be reduced to 500 assault drones.[68] Just previous to this Admiral Towers informed Admiral Horne the assault drones were being procured for combat use by midsummer of 1943. He also informed him that he was—

—considerably concerned over premature commitments of funds, materials and personnel to this project which otherwise would be available for current needs.[69]

In the meanwhile, greatly improved radar-control, target-seeking, and target-homing equipment had been developed. The Radio Corp. of America, when called upon to develop a sensitive radio reflection altimeter, had placed the project under the supervision of Dr. Irving Wolff and made Mr. R. C. Sanders, an electronic engineer, the project engineer. As soon as Sanders began obtaining good results with the device he suggested the use of it to determine the presence of an object directly ahead. This device, termed a "sniffer," differed from an altimeter only in that it operated in the horizontal instead of the vertical plane. In addition to determining the presence of a target ahead, it could cause a torpedo to be launched or a bomb to be dropped at a selected distance from a target. Lt. M. B. Taylor, USN, of the Naval Aircraft Factory, suggested that right and left switching be added to make the device target-seeking. This was included, and in the summer of 1942 was tested and operated satisfactorily for ranges up to 4,000 yards.[70]

[68] Letter, dated 12 Aug. 1943, Chief of Naval Operations to the Chief of the Bureau of Aeronautics, file F31–1 (43) (058912).

[69] Letter, dated 6 Aug. 1942, Chief of the Bureau of Aeronautics to the Vice Chief of Naval Operations, file F31—(43).

[70] Status report, Dr. Irving Wolff, Radio Corp. of America, January 1943.

Following these tests, the Radio Corp. of America successfully developed the RL 101 "sniffers," and produced 10 of these equipments, which would, upon discovering a target, lock on and launch a torpedo or drop a bomb automatically at a preset distance from it. At the same time a parallel project was established to develop the RL 102 "supersniffer," capable of doing all the RL 101 could, but with the additional capability of searching an arc and then locking upon a discovered target. In November 1942, specifications for this device requiring range of 2 miles, later increased to 6 miles, were drawn up and approved by the Bureau of Aeronautics.

By April 1943 the "sniffer" gave satisfactory releases of bombs at speeds between 130 and 180 knots, and by May the lower limit had been decreased to 90 knots. At this time, tests of the "supersniffer" were also producing good results on ships and lighthouses at distances of 4 to 5 miles at an altitude of 50 feet and at ranges of 6 to 8 miles at altitudes between 200 and 300 feet. Since the requirement for the supersniffer was 6 miles at low altitude, it was necessary to change the power and frequency of the equipment. However, a drone had been flown into an area and had sought out and locked upon a moving tanker at a distance of 2 miles. This was the first successful radar homing test on a moving target conducted by anyone.

These successes were reported by Wolff at a conference held prior to 28 June 1943. At this same conference Fahrney stated that the supersniffer project was of the greatest importance; that next to it was its application to the glide bomber; and third in importance was the development of a surface air-to-air missile in the 1500–4000-mc. band.

The first 12 assault drones were delivered in December and turned over to the Board of Inspection and Survey for trials. The Board made its report on 19 January and concluded with,—

—it is recommended that immediate steps be taken to develop an adequate control installation in the most advanced type of high performance bomber which can be made available, in order that control equipment made be made available if, and when drones of corresponding capabilities are desired.[71]

Following further tests of these 12 assault drones during the first months of 1943, Smith submitted a progress report covering, among other things, the developmental and service testing of the weapon including details of the guidance and control systems. He indicated that it was superior to a gun, bomb, or torpedo in accuracy and possessed ability to make an accurate horizontal approach against objectives that could not be reached by other weapons. He recommended that this "airborne remote-control bomb" be brought into action by trained crews and that it be used during periods of low visibility, boldly, and in sufficient force to gain full benefit of its power and surprise characteristics.[72]

Admiral King was inclined to approve Smith's recommendations but prior to doing so desired information relative to organizational planning.[73] This was submitted to him in a plan which called for 3 combat units of 99 control planes, 891 drones, 441 officers, and 3,210 enlisted personnel, plus a training force of 12 control planes, 45 drones, 259 officers, and 2,238 enlisted personnel.[74] After insuring that this was agreeable to the Chief of the Bureau of Aeronautics, King, on 23 March, approved it with the admonishment that the secrecy of the weapon would be maintained and information concerning it limited to those who must know.[75]

On the same day, Horne directed that the program be increased to a total of 3,000 assault drones and that a delivery rate of 250 per month be achieved by June 1944.[76]

Again the Chief of the Bureau of Aeronautics expressed concern over the requirements of the program and the ability to provide the 3,000 drones, necessary pilots, and other personnel, without serious interference with the regular aircraft program.[77] In conferences which followed, the program was reduced to 1,500 drones in addition to the 500 already under contract.

In order to carry out the various types of combat missions visualized, each of these 2,000 planes required being configured for and fitted with radio control equipment, radio altimeter, television, automatic bomb-release device, radar beacon, and radar equipment.

Frequency modulated radio control equipment was placed under contract with the F. M. Link Co. of New York. The Radio Corp. of America was given the contract for the altimeter, television, automatic bomb release, and homing equipment. The first television equipments used frequencies of about 100 mc. Later, equipment was developed in the band between 264 and 312 mc. Development of experimental television systems at about 1000 mc. was conducted by the Philco Corp. of Philadelphia and at about 1800 mc. by the General Electric Co. at Schenectady.

On 22 September 1943, Admiral King directed the Vice Chief of Naval Operations to "take in hand the active coordination and expediting of all guided-missiles development and research projects and press them to the earliest possible availability for service use." [78] As a result of this

[71] Letter, dated 19 Jan. 1943, President, Board of Inspection and Survey, to the Chief of the Bureau of Aeronautics, file, Radar Installations.

[72] Letter, dated 8 Mar. 1943, Officer in Charge, Project Option, to the Vice Chief of Naval Operations, file OP–12 (s) –aw.

[73] Memorandum, dated 13 Mar. 1943, Admiral King to Admiral Horne, file Op–292.

[74] Memorandum, dated 16 Mar. 1943, Vice Admiral Horne to Admiral King, file Op–292.

[75] Memorandum, dated 22 Mar. 1943, Vice Admiral Stone to Admiral King, file Op–292; Letter, dated 23 Mar. 1943, Commander in Chief, U.S. Fleet, to the Chief and Vice Chief of Naval Operations, file F31 –1.

[76] Letter, dated 23 Mar. 1943, Vice Chief of Naval Operations to the Chiefs of the Bureaus of Personnel, Aeronautics, Ordnance, and Ships and to commander, Training Task Force, file F31–1.

[77] Letter, dated 12 Apr. 1943, Chief of the Bureau of Aeronautics to the Vice Chief of Naval Operations, file F31–1.

[78] Letter, dated 22 Sept. 1943, Commander in Chief, Pacific Fleet, to the Vice Chief of Naval Operations, file Op–292.

directive, Admiral Horne dispatched Smith to the Headquarters, Pacific Fleet, to discuss the combat employment of drone missiles in that theater. Since the war in the Pacific had changed from a static one to one of forward motion, and since conventional weapons were proving capable of winning the war, Admiral Nimitz, on advice of his staff and subordinate commanders, was against upsetting scheduled operations to experiment with an unproven weapon. He felt that he could spare neither carriers nor fields for this purpose. Heavy commitments of carriers in support of MacArthur made it necessary to utilize every available one in task forces in support of island-hopping or in containing the Japanese Fleet during the course of such operations. His decision was further based on the low speed and maneuverability of the assault drones, and he specifically recommended that SBD's, if suitable and available, be converted into drone missiles.

Following this, training and evaluation of the program continued, but no endeavor was made to utilize them in combat because King and Horne still desired that, when utilized, they be used in quantity and in continuity.

On 15 February 1944, Capt. H. B. Temple, USN, became head of the guided-missile program in the Office of the Chief of Naval Operations. He immediately made a study of the program, and in a memorandum to the Commander in Chief, U.S. Fleet, advised that, because of the time and space requirements of the Pacific war, target availability, and because of the fast movement of our forces, a declining requirement for a weapon such as the assault drone was indicated. He recommended that the program be drastically reduced and changed to a "combat test" one. This was in consonance with the opinions of Towers and Stevens, Head of the Research and Development Branch of the Bureau of Aeronautics. Temple's recommendations were approved. In March 1944, a planning directive was issued reducing the number of assault drones to a total of 388. No reduction was made in the orders for electronic equipment because it was considered that these devices could be used in obsolete planes.[79] On 10 March, the operating force for delivering the assault drone attacks was reduced to four operating and one headquarters squadron.

After further reviewing the program, Temple, who believed that the preponderant offensive power of naval aviation was vested in carrier-based planes, found that the assault drones, as then configured, could not be controlled by carrier-based planes. He found that the Army had developed two prototypes which could be used, and he recommended all effort be made toward the utilization of these.[80]

Temple's comments were forwarded to Admiral King, who, on 10 April, stated:

> The deficiency of this program, as far as increasing the striking power of the aircraft carrier squadrons is concerned, is recognized and the evidence of this deficiency led to the appointment of the Vice Chief of Naval Operations as coordinator and guide for this program.

King followed this by directing the Vice Chief of Naval Operations to take action—

> to insure energetic and properly directed efforts are put forth on the development of projects that show promise of providing useful weapons for carrier squadrons.[81]

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[79] Memorandum, dated 5 Mar. 1944, Admiral King to the Secretary of the Navy, file Op—292.

[80] Memorandum, dated 30 Mar. 1944, Deputy Chief of Naval Operations (Air) to Commander in Chief, U.S. Fleet, file Op—292.

[81] Memorandum, dated 10 Apr. 1944, Admiral King to the Vice Chief of Naval Operations, file Op—292.

CHAPTER XLI

The Proximity Fuze

THE NAVAL FIRE-CONTROL PROBLEM

The control of projectiles fired from a moving and unsteady platform is one of the most difficult procedures of warfare. The difficulties increase rapidly with range and motion of target and are still further increased when a very small high-speed target is capable of motion in both vertical and horizontal planes and can make radical course and speed changes. The problem must be solved instantaneously and produce absolutely correct course, speed, range, bearing, and position angle, otherwise the predicted point of contact of projectiles and target will be in error and the target will continue undamaged. A duck hunter instinctively takes these variables into account when he takes a lead on his fowl, but he does not have to determine the instant of exploding his charge for that is done at the time of firing, and his charge goes out covering a space that increases rapidly until its range is reached. In long-range firing against aircraft this variable, the time of flight of the projectile until it reaches the proper position in relation to the target, must be considered. At the instant it reaches this position the fuze must detonate the projectile.

With a visible target on a steady course at constant speed, the bearing and position angle can be continually supplied the fire-control equipment electrically. Prior to World War II and the concurrent development of radar, an approximation of range was made by optical equipment and supplied manually to the fire-control equipment. With these three variables the fire-control equipment could determine course and speed and predict future position. However, there was the required estimation of fuze setting, any error in which created a corresponding error in burst. The development of fire-control radar increased range accuracy and allowed it to be fed electrically to the fire-control equipment. There were still inaccuracies in fuze settings which increased with the shorter and shorter solution periods brought about by increased target speeds. Even with extremely accurate bearing, position angle, and range being provided the fire-control equipment to permit it to generate predicted position and to provide gun-laying data, the errors in fuze settings necessitated saturation firing. This was not too effective a defense and its effectiveness decreased more than proportionally with the number of different directions in which the attacking planes came in.

The requirement for a fuze which would detonate a projectile when its target was within its burst range (approximately 70 yards for a 5-inch projectile) was obvious, the means of accomplishing this were not. The ultimate solution is a tribute to the Navy, American scientists, and the American electronics industry.

EARLY ATTEMPTS TO DEVELOP A PROXIMITY FUZE [1]

For a decade prior to World War II, the Navy's Bureau of Ordnance had considered

[1] Rowland and Boyd, "U.S. Navy Bureau of Ordnance in World War II," Washington, Government Printing Office, 1953, pp. 276–278.

the possibility of developing an infrared fuze which could be triggered by the heat developed by an aircraft engine. The complicated engineering problems involved had proven too great an obstacle to its development.

In the summer of 1940 improved capabilities of aircraft and the precarious international situation necessitated exploration of the entire scientific field, with the highest priority, to the end that a fuze be developed which would detonate a projectile when in proximity of an aircraft. During July meetings a group, constituted of members of the National Defense Research Committee and the Navy Department Council for Research, decided that the development of such a fuze was possible by utilizing either electronic or photoelectric devices. There were no stipulations as to the techniques to be investigated. One month later, the Bureau of Ordnance gave influence fuzes top priority over all projects that it had requested the National Defense Research Committee to investigate.

Later in that month, it was learned that two of our largest electronics manufacturers were providing the British with thousands of vacuum tubes and photoelectric cells. This lead to the belief that they were being used for some type of proximity fuze. Following the arrival, in September 1940, of the British Technical Mission, headed by Sir Henry Tizord, this suspicion was confirmed by a presentation of a summary of their unsatisfactory progress in that field.

During August 1940, Section T of the National Defense Research Committee was established under Dr. M. A. Tuve of the Carnegie Institution. Arrangements were made for the research to be conducted at the laboratory of the Department of Terrestrial Magnetism of the Carnegie Institution, Washington. In November 1940, the Bureau of Standards joined section T on the project and for a few months both of these activities conducted independent research, each working on a variety of devices applicable to a wide range of projectiles. Since the Navy's basic and urgent requirement was for a fuze for antiaircraft projectiles, fired from rifled guns, the work of the two activities was separated in July 1941. Thereafter, Section T devoted its entire energies to this problem, while the Bureau of Standards concentrated on influence fuzes for nonrotating projectiles.

In November 1941, the Bureau of Ordnance contracted with the Crosley Corp. to conduct independent research in fuze construction under the technical supervision of the National Defense Research Committee. This industrial concern was expected to provide realistic engineering design rather than development. Meanwhile, the National Defense Research Committee had made and was continuing to make contracts with numerous companies and universities. The pace of development was so rapid that it exceeded all available research facilities.

The growth of the project was so great that it required increased administrative support. Accordingly, in March 1942, it was placed directly under the Office of Scientific Research and Development, which contracted with Johns Hopkins University to provide for its administration. The secret classification of the project necessitated the provision of secure space for this. The University established the Applied Physics Laboratory at Silver Spring, Md., a suburb of Washington. This Laboratory quickly became the focal point of the project.

During the early months acoustic, thermal, electrostatic, and magnetic types were studied and then abandoned as unsatisfactory. Considerable emphasis was placed on the utilization of photoelectric cells and one was practically completed in early 1941, but the cells failed to withstand the centrifugal force developed by the rotating projectile. Moreover, such a fuze was unsatisfactory since it required daylight for operation.

THE DEVELOPMENT OF THE PROXIMITY FUZE [2]

In early 1941, all contractors supported by

[2] Ibid., p. 278.

Navy funds were directed to concentrate on the development of an electronic fuze. Several means were immediately studied. Among these was one in which the transmission of radio waves from the ground would be reflected by the target and received by and activate the fuze. Another, more logical and the ultimately accepted approach, was to develop a fuze which was capable of obtaining its own intelligence and of using it to ignite the demolition train. In completed form, this fuze would consist of four principal components: A minute radio transceiver, complete with amplifier and capacitor; a battery; an explosive train; and the necessary safety devices. The theory was that the fuze transmitter, alone, would not produce sufficient signal intensity to trigger a thyratron tube switch. However, as the projectile approached a target the radio waves reflected by the target would gradually increase and come more and more into phase with the fuze- generated signal until by the time it was within the fragmentation pattern the intensity of the combined waves would trigger the thyratron tube switch. This would, in turn, release the energy in a charged condenser which would ignite the explosive train. Schematically, it had the appearance of a Rube Goldberg creation. Actually, it was a brilliant conception. To convert it to a workable device required the development of radio components rugged enough to withstand an accelerative force 20,000 times stronger than gravity and a centrifugal force set up by approximately 500 rotations per second, yet small enough, together with the other three components, to be contained in a space approximately the size of a pint milk bottle.

Had the requirement for miniature components of the required ruggedness been submitted to any electronic equipment manufacturer during peacetime he would have most probably shaken his head and declared them far beyond the engineering capabilities of his staff. However, the increased defense such a fuze would provide our ships and cities was sufficient to cause them to make the endeavor. Miniaturization had already had a start in the manufacture of electronic hearing aids but ruggedness was not an essential requirement of that field.

During the development period, the tubes were handmade by engineers of the Western Electric, Raytheon, Hytron, Erwood, and Parker-Majestic Cos. As might be expected, quality varied but intermittent tests conducted throughout the latter half of 1941 offered promise. Wherever weakness was found it was corrected by redesign and strengthening until eventually satisfactory handmade products which were capable of tooled mass production became available.

On 29 January 1942 a group of fuzes with miniaturized components and dry cell batteries, assembled on a pilot line, were installed in standard 5-inch antiaircraft projectiles and fired from a 5-inch 38-caliber antiaircraft gun. At the end of a 5-mile trajectory 52 percent successfully activated themselves by proximity to water. This might appear to be a low percentage but this offered protection far greater than that afforded by saturation firing. The Bureau directed the Crosley Corp. to commence pilot production of the fuzes without delay. At this time it was given the designation VT (variable time).

During the drawing-board stage of the fuze, it had been considered that a small dry cell battery would provide a satisfactory source of energy. During the development period it was found that these batteries often failed to withstand the shock of gunfire and, moreover, were of short life under shipboard storage conditions. Especially in the South Pacific, continued use of this type would require their constant replacement and would cast doubts as to the reliability of the fuze. Parallel research to develop improved dry cells and a wet battery, wherein the electrolyte would be kept separated from the electrode until after the projectile was fired, was concentrated at the Cleveland, Ohio, plant of the National Carbon Co. The latter type proved feasible and was developed into a cylindrical battery, resembling a fountain pen, wherein the electrolyte is contained in a glass ampule at the center of a cylindrical cell of thin plates. Upon the firing of the projectile the shock breaks the ampule, the electrolyte is released and the centrifugal force generated by the rotation of the projectile forces the liquid between the plates and activates the battery. This battery was ready for experimental testing in February 1942.

Development of the fuze continued concurrently with the pilot production at the Crosley Corp. plant. In April 1942, firing tests, in which the new battery was utilized, were conducted successfully, using a small plane suspended from a barrage balloon as a target. Following this, extensive work was conducted to adapt the necessary safety and self-destruction devices to the fuze. After conducting another test, similar to the one conducted on 29 January, 70 percent of the fuzes detonated, and a decision was reached to conduct a shipboard firing test.

SERVICE TEST OF THE VT FUZE [3]

On 12 August 1942, the first precombat service tests were made by the newly commissioned U.S.S. *Cleveland,* Capt. S. E. Burroughs, USN, commanding, then shaking down in the Chesapeake Bay. Radio-controlled planes (drones) were used as targets. The Gunnery Officer, Lt. Comdr. Russell Smith, USN, was an experienced fire-control officer. His guncrews consisted of approximately 10-percent experienced personnel with the remainder being newly enlisted, who were serving on their first ship. Smith, with his nucleus of experienced personnel, worked assiduously before and during the shakedown period to train his fire control and guncrews and achieved magnificent results. The tests were scheduled for a period of 2 days and were to be conducted under simulated battle conditions. All three available drones were destroyed early on the first day, while their controllers were putting them through all possible evasive maneuvers, by the bursts of four proximity fuzed projectiles. This was an astounding and pleasant sight to all who witnessed it and it was especially so to those who had served in the task force which had made the strikes against the Marshalls, Wake, and Marcus in the early months of 1942, and were aware of the impotency of our antiaircraft defense. Here was a device which would force enemy aviators to be more respectful of distances or else activate our fuzes to accomplish their own destruction.

EARLY PRODUCTION UNDER FLUID SPECIFICATIONS [4]

Following the *Cleveland* tests fluid specifications, which permitted incorporation of later developments, were drawn up for mass production of the fuze and manufacture was commenced. Those produced were shipped to the Ammunition Depot, Mare Island, Calif., for assembly into antiaircraft projectiles. Samples of these were flown back daily to the U.S. Naval Proving Ground, Dahlgren, Va., for verification of quality.

INITIAL COMBAT USE [5]

When, in the middle of November 1942, 5,000 rounds of proximity-fuzed projectiles were in storage at Mare Island, they were rushed to Noumea for distribution to ships of a task force in the southwest Pacific. The first ship to introduce them to the enemy was the U.S.S. *Helena.* On 5 January 1943, four Japanese bombers attacked the task force and the *Helena* downed one with the second salvo of proximity-fuzed ammunition.

[3] The author, then serving in the U.S.S. *Cleveland,* was an eye witness to these firings.

[4] Rowland and Boyd, op. cit., p. 283.

[5] Ibid.

SECURITY RESTRICTIONS ON USAGE [6]

Realizing the necessity of keeping the details of the fuze from the enemy, the Combined Chiefs of Staff issued a ban against its use in any locale where a dud or live ammunition might be recovered by the enemy. This restricted its usage to naval warfare and also prevented it from being used in naval bombardment of enemy-held territories.

FULL-SCALE PRODUCTION [7]

Following the Crosley Corp. contract, production was increased with great rapidity. Beginning in September 1942, newly established facilities commenced producing the rugged miniature tube in large quantities. In October 1942 an average of 500 tubes were being manufactured daily. After the fuze had been proven in combat the expansion of manufacturing facilities was rapidly increased. By the end of 1943 almost 2 million had been delivered. By the end of 1944, 87 contractors, operating 110 plants, were manufacturing parts of the fuze which at that time were being delivered at the rate of 40,000 per day. Procurement contracts increased annually from $60 million in 1942, to $200 million in 1943, to $300 million in 1944 and were topped by $450 million in 1945. The increased volume and improved production techniques lowered the cost per fuze from $732 in 1942 to $18 in 1945. This permitted the purchase of over 22 million fuzes for approximately $1,010 million.

Fuze assembly was concentrated in the plants of the Crosley Corp., the Radio Corp. of America, the Eastman Kodak, and the McQuay-Norris Cos. Mass-tube production finally had to be limited to Sylvania Electric Products, Inc., since they proved to be the only firm capable of combining quality and quantity. Cost of tubes declined with increased production from $5.05 in 1942 to $0.40 in 1945.

COMBAT USAGE DURING 1943 [8]

During 1943 approximately 9,100 rounds of proximity-fuzed and 27,200 rounds of time-fuzed 5-inch antiaircraft projectiles were fired. Fifty-one percent of the hits on enemy planes were credited to VT-fuzed projectiles. Its success in repelling air attacks against fleet units reached its peak when a task group in the Pacific reported the destruction of 91 of 130 attacking Japanese planes. It was being used with like effect against the enemy in the Mediterranean and Atlantic theaters.

REMOVAL OF SECURITY RESTRICTIONS AND COMBAT USAGE DURING 1944 [9]

During 1944 happenings of dire nature in the European theater of operations necessitated the lifting of the ban against the use of the fuze where it might be recovered by an enemy. On 12 June 1944 the first "buzz bomb" fell on London and it was followed by steadily increasing numbers. The all-out valiant effort of the Royal Air Force failed to cope with the new weapon. The Combined Chiefs of Staff reluctantly agreed upon the necessity of using the proximity fuze in the defense of London. Large numbers of antiaircraft guns were moved to the channel coast where they could fire at the bombs over water. Success in destroying the bombs by gunfire increased proportionally with the increase in the use of VT-fuzed projectiles. In the last month of the terrifying 80 days, 79 percent of the bombs engaged were destroyed as

[6] Ibid., p. 286.

[7] Ibid., p. 285.

[8] Ibid., pp. 286–287.

[9] Ibid., pp. 288–290.

compared with the 24 percent destroyed during the first week of the attacks. On the last day of large-scale attacks only 4 of 104 bombs succeeded in reaching their target. Some of the 100 destroyed are credited to the Royal Air Force and to the barrage balloons but the majority were victims of proximity-fuzed projectiles. There was little profit to the enemy with such a minute percentage of success so he turned the weapon on the port of Antwerp which at that time was vital to the Allied supply lines. In the autumn of 1944 the devastating damage wrought while the Allies were redeploying antiaircraft guns threatened to close the port. As the number of guns firing the proximity fuze increased, the damage decreased and the Allies were able to move their guns closer and to assume the offensive against the aerial targets. The defense of Antwerp resulted in the Combined Chiefs of Staff removing all bans against the use of the fuze and this was most fortunate. In late December 1944, von Rundstedt launched a counterattack which developed into the Battle of the Bulge. The use of the fuzes entered a new field, that of artillery fire against ground forces. The results of this usage were devastating to German troops and put fear into their hearts. No longer were their foxholes havens against shrapnel burst for with the use of the "funny fuze," as it was termed by General Patton, the shrapnel bursts occurred before the projectiles hit the earth, showering areas with high-velocity fragments.

EPILOG

The proximity fuze was one of the major contributions of American scientists, engineers, and manufacturers to the winning of the war. Security prevented them from receiving the plaudits they so well deserved but they had full payment in the knowledge of their own great contributions. General Benjamin Lear, USA, described it as "the most important new development in the ammunition field since the introduction of high-explosive projectiles." General George Patton, USA, likewise paid tribute to its developers, stating, "I think when all armies get this shell we will have to devise some new method of warfare." Patton's prophecy might well have come true except that within the year, this great electronic achievement of combined United States science, industry, and naval endeavor was dimmed by the devolpment of greater and more damaging concentrated explosive power than the world had ever experienced. Even this development necessitated the continued use of the proximity fuze in the control of its point of detonation.

CHAPTER XLII

Radio Conferences During the Period Between World Wars

PREFACE

At the First International Radio Conference, held in Berlin in 1903, delegates of the powers represented drafted a protocol governing the use of radio to be considered by a second conference to be assembled a year later. The Second International Conference, postponed by the Russo-Japanese War, met again in Berlin in 1906 and essentially agreed to these previously drafted agreements and regulations. The U.S. delegates took a leading part in drafting this covenant but unfortunately the Senate delayed ratifying it until 1912. Late in that year the Third International Conference convened in London and took actions to increase the utilization and regulation of radio to enhance safety of life at sea. At this time a decision was reached to hold the Fourth International Radio Conference during 1917. The U.S. Government extended an invitation to hold this in Washington. This invitation was accepted but as a result of World War I it was not convened until 1925.[1]

ALLIED RADIO CONFERENCE

In 1921 representatives of the United States, France, Great Britain, Italy, and Japan met in Washington to discuss the international use of radio and to draft a protocol for consideration at the Fourth International Radio Conference. These representatives formulated a series of technical questions which could not be answered at the time and directed the assembling of a Technical Committee on International Radio Communications in Paris at the earliest possible time to consider and advise upon these questions. This Committee met from 21 June to 22 August 1921 and gave recommendations in the premises. In closing, the Committee recommended that the United States, being charged with calling the next international conference, should accept the task of preparing a revised presentation of the Washington draft, which would include the proposals presented by the Technical Committee, and communicate this to the other nations with an invitation to attend the Conference. It further recommended that these nations should transmit, within a definite period, all their objections, observations, and proposals with the understanding that no new matters would be presented during the Conference. Following receipt of objections, observations, and proposals the United States was to transmit them to all attending nations in sufficient time to permit at least 6 months for their consideration prior to the convening of the Conference.[2]

NATIONAL RADIO CONFERENCES

Suddenly and unheralded, in 1921 radio broadcasting created one of the most fan-

[1] Supra, Ch. XII.

[2] "Report of the Technical Committee on International Radio Communications," p. 2.

tastic booms in the history of the American people. Without prospect of monetary gain, unless the applicant was a manufacturer or purveyor of radio equipment, increasing numbers of requests for station licenses for broadcasting purposes poured into the Department of Commerce. Under the Radio Act of 1912 no power existed permitting the denial of a license to any reputable American citizen. At the time there were only two authorized frequencies for broadcasting purposes, 830 and 1620 kc. By 1922 the conditions became so chaotic that President Harding directed Secretary of Commerce Herbert Hoover to convene a conference of manufacturers, broadcasters, radio amateur spokesmen, and civilian and military government radio communication personnel to study the problem and to make recommendations to alleviate the intolerable situation.

In his opening speech to the members of this First National Radio Conference Secretary Hoover remarked:

> We have witnessed in the last four or five months one of the most astounding things that has come under my observation of American life. This Department estimates that today more than 600,000 persons possess wireless telephone receiving sets, whereas there were less than 50,000 such sets a year ago. We are indeed today upon the threshold of a new means of widespread communication of intelligence that has the most profound importance from the point of view of public education and public welfare.[3]

Although acrimony quickly developed between the several factions striving to gain control of the recently developed medium, all were in agreement that a definite U.S. radio policy was needed and that Federal control was essential.[4]

The conferees recommended that the public and the Government have priority rights in the use of radio and that the existing inadequate laws should be changed to give the Government control over all transmitting stations. They recommended no restrictions upon the use of receivers but reannunciated the inviolability of the contents of private and official messages.

Four classes of broadcasting were recommended:

> Government;
>
> Public, by States, universities, and others disseminating educational information;
>
> Private, by stores, newspapers and others distributing news, entertainment or other services; and,
>
> Toll, by public service radio telephone companies as a paid service.[5]

The increase in broadcasting stations necessitated that an increase in broadcasting frequencies be recommended. This required the invasion of that portion of the spectrum between 185 and 500 kc., formerly reserved for military and naval usage by national and international laws. Governmental broadcasting was allotted two frequency bands, 146 to 162 and 200 to 285 kc.; private and toll broadcasting was allotted the band 700 to 965 kc., public broadcasting was allocated the band between 1053 and 1090 kc.; and the amateurs were allowed the exclusive use of the band between 1500 and 2000 kc. and the frequency of 910 kc. plus the shared usage of the band 090 to 1500 kc. with technical and training schools. No material changes in the frequencies utilized by ships, aircraft, fixed stations, radio beacons, and radio compass stations were recommended.[6]

In view of the amount of commercial advertising on radio and television channels today it is of interest to note that this Conference recommended against this obnoxious means of advertising by limiting it to the announcement of the name of the program sponsor.

It was recommended that the Secretary of Commerce be given the power to prohibit the use of radio-transmitting apparatus and methods which created unnecessary interference provided more satisfactory apparatus and methods should become reasonably and commercially available.[7]

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[3] Gleason L. Archer, "History of Radio to 1926," the American Historical Society, Inc., New York, 1938, pp. 248–249.

[4] Ibid.

[5] Popular Radio, 1922, p. 61.

[6] Ibid., p. 62.

[7] Ibid.

Recognizing that radio interference was one of the major problems of broadcast reception, the members submitted the following program for the study by the U.S. Bureau of Standards:

The reduction of the rate of building up of oscillations in radiating systems;
The reduction of harmonics in continuous wave transmitters and of irregularities of oscillation;
Comparison between the variable amplitude and the variable-frequency methods of continuous wave telegraphy;
The preferable methods of telephone modulation to avoid changes in the frequency of oscillation;
The proper circuit arrangements of regenerative receivers to avoid radiation of energy;
The use of highly selective receiving apparatus, including a list of approved types;
The use of receiving-coil aerials instead of antennas, with special reference to high selectivity;
The reduction of interference with radio communication by other electrical processes, such as X-ray apparatus; and,
The study and standardization of frequency meters.[8]

In September 1922 Congressman Wallace H. White, Jr., of Maine, who had been a voluntary member of the First National Radio Conference, introduced a bill which embodied the recommendations of that Conference. The November issue of Radio Broadcast reported that this was "lost in the mazes of congressional procedure." Congress, always reluctant to enact legislation controlling radio, simply could not get the bill reported out of committee.[9]

The Second National Radio Conference was held in 1923 but, without enabling legislation, the members could only reiterate the recommendations of the previous Conference. By the middle of 1923, 143 radio broadcasting stations had closed because of lack of income and the insistence of the writers of popular music that they be paid royalties for its use in radio broadcasting.[10]

The failure of Congress to pass the White Radio bill convinced Secretary Hoover that he would be granted no authority in excess of that which he already possessed. With the concurrence of the major broadcast executives he issued a reassignment of frequencies for broadcasting stations in July 1923. Radio Broadcast for the following month stated:

. . . the Secretary of Commerce, acting in accord with the opinion of the radio experts and authorities of the country has reassigned frequencies to practically all the broadcasting stations in the country and has done it so well that we no longer have any cause for complaint. Instead of the bedlam of noise to which we had become almost accustomed, there is practically no interference at all.[11]

This new system, which worked for a few weeks, had no compelling basis of law and unscrupulous and selfish individuals soon ruined the Secretary's excellent plan and the situation returned to its former chaotic condition.[12]

The Third National Radio Conference convened in Washington on 6 October 1924. This was by far the most important of these Conferences. The present allocations of frequency bands stems from its recommendations. Military and naval communication systems voluntarily agreed to use the broadcast band 500–1600 kc. only on a noninterference basis. As a result of this shifting of frequency bands the Navy drew up its first complete radiofrequency plan which was approved by the President upon the recommendation of the Interdepartmental Radio Advisory Board. Later this plan became the basis for an international allocation of frequency bands.[13]

In this Conference the members unselfishly endeavored to solve the problems of radio usage. This is amazing when one considers that it was held at the time when a controversy over broadcasting rights was being waged between the radio and telephone groups. Amateurs cooperated by voluntarily agreeing to abolish the use of spark transmitters and to discourage the use of oscillating receivers within the broadcast band.[14]

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[8] Ibid., p. 63.
[9] Gleason L. Archer, "History of Radio to 1926," the American Historical Society, Inc., New York, p. 281.
[10] Ibid., p. 317–318.
[11] Ibid.
[12] Ibid.
[13] Ibid., pp. 350–351.
[14] Ibid., p. 351.

One of the most significant and controversial events of the Conference was the advocation by Mr. David Sarnoff, Vice President of the Radio Corp. of America, of the establishment of a chain of 50-kw (superpowered) broadcast stations. This proposal was finally compromised by recommending the Secretary of Commerce issue licenses for such stations which could be revoked if it should be found by experience that they interfered with other stations.[15]

The recommendations of the Conference resulted in dividing broadcasting stations into the three following classes:

Class	*Kilocycles*	*Number of channels*
1	550–1,070	63
2	1,090–1,400	32
3	1,420–1,460	5

This provided for an increase of 10 channels for class 1 stations and the elimination of broadcasting below 550 kc.[16]

For the first time in the U.S. allocations of frequencies bands above 2000 kc. were considered and the following usage was suggested:

Kilocycles	*Service*
95–120	Government, CW and ICW, exclusive.
120–157	Marine, CW and ICW, exclusive.
157–165	Point-to-point, CW and ICW. Marine, CW and ICW.
165–190	Point-to-point, CW, ICW, spark. Marine, CW and ICW.
190–230	Government, CW and ICW, exclusive.
230–235	University, college, and experimental, CW and ICW, exclusive.
235–250	Marine, phone, nonexclusive.
250	Government, CW, ICW, nonexclusive.
250–275	Marine, phone, nonexclusive.
275	Government, CW, ICW, nonexclusive.
275–285	Marine, phone, nonexclusive.
285–500	Marine and coastal, including radio compass and radio beacons.
500–550	Aircraft, CW, ICW, phone and fixed safety-of-life stations, phone, exclusive.
550–1,500	Broadcasting services, phone, exclusive.
1,500–2,000	Amateur, CW, ICW, phone.
2,000–2,250	Point-to-point, nonexclusive.
2,250–2,500	Aircraft, exclusive.
2,500–2,750	Mobile.
2,750–2,850	Relay broadcasting, exclusive.
2,850–3,500	Public service.
2,500–4,000	Amateur and Army mobile.
4,000–4,500	Public service and mobile.
4,500–5,000	Relay broadcasting, exclusive.
5,000–5,500	Public service.
5,500–5,700	Relay broadcasting, exclusive.
5,700–7,000	Public service.
7,000–8,000	Amateur and Army mobile.
8,000–9,000	Public service and mobile.
9,000–10,000	Relay broadcasting, exclusive.
10,000–11,000	Public service.
11,000–11,400	Relay broadcasting, exclusive.
11,400–14,000	Public service.
14,000–16,000	Amateur.
16,000–18,000	Public service and mobile.
18,000–56,000	Beam transmission.
56,000–64,000	Amateur.
64,000–infinity	Beam transmission.[17]

[15] Ibid.

[16] "Recommendations For The Regulations Of Radio," adopted by Third National Radio Conference, Washington, Government Printing Office. 1924, p. 17.

[17] Ibid., p. 15.

The Committee on Marine Communications recommended allocation of the frequency bands recommended for this service as follows:

Kilocycles	
120–190	Unassigned, except as noted below, with the recommendations that allocations to various marine services be made by the Department of Commerce.
160–175, and 185	Government use. It was further recommended that the frequency of 185 kc. be used for ice-patrol broadcasting and for other navigational aid messages.
235–285	Marine radiotelephony. It was recommended that specific allocations within this band should be made by the Department of Commerce and, pending further developments, should be tentative.
343, 410 and 454	Ship-to-ship and ship-to-shore communications.

Kilocycles	*Service*
425	It was recommended that ships now assigned this frequency be assigned other frequencies within a reasonable time.
315	Government use.
345–410	Radio compass.
445	Government use for aircraft and submarines, CW and ICW.
500	Exclusive for calling and distress signals and messages relating thereto.
2,750	Mobile marine services.[18]
2,500–	

[18] Ibid., pp. 20–21.

The Fourth National Radio Conference was convened in the autumn of 1925. The Secretary of Commerce had practically been forced to abandon his policy of issuing licenses to all applicants, for despite numerous failures of broadcasting stations, applications for new licenses increased by leaps and bounds. The Secretary keynoted his opening speech of this Conference by declaring the radio industry should solve its problems by private initiative and not be too ready to ask the Government to assume the responsibility. However, the members were almost unanimously in favor of the Department of Commerce in illegally assuming the responsibility, for reducing and limiting the number of stations. The Secretary yielded to this recommendation and assumed the authority.[19] He also entered into an agreement with the Canadian Government which allocated the use of six broadcasting channels for the exclusive use of their broadcasting stations. Meanwhile, the Zenith Radio Corp. had applied for license for a station in Chicago. This was granted and the station was assigned a frequency shared with a General Electric Co. station in Denver. Only a few hours a week were available to the Chicago station. This was unsatisfactory to Zenith officials who requested the assignment of one of the channels which had been allocated to Canada. Their request was denied. They then ignored the prescribed rules and the Zenith Co. was promptly sued by the Government. On 16, April 1926, a decision was rendered which did not uphold the right of the Department of Commerce to assign frequencies. The Attorney General of the United States was forced to issue the edict that the Secretary of Commerce had no power to withhold licenses from reputable U.S. citizens, nor authority to prescribe frequencies for or hours of operation of stations. With the last vestige of control removed one can readily picture the conditions which immediately ensued. This country, scheduled to be the host nation for the first International Radio Conference since 1912, unable to control an industry within its own boundaries and unable to enforce international agreements, set a horrible example for the remainder of the world.[20]

[19] Gleason L. Archer, "History of Radio to 1926," the American Historical Society, Inc, New York, 1938, p. 367.

THE FEDERAL RADIO COMMISSION

Immediately following the edict issued by the Department of Justice a new bill establishing a Federal Radio Commission, with authority to allocate commercial frequencies and hours of usage as well as to prescribe and supervise radio discipline, was agreed upon. This action was taken too late for the bill to be enacted into law prior to the adjournment of Congress. It was considered and passed in early 1927 and was signed by President Coolidge on 23 February 1927. The new established commission consisted of five members. The President immediately nominated Rear Adm. W. H. G. Bullard, USN (retired), as chairman and Messrs. Orestes H. Caldwell, Eugene O. Sykes, Henry A. Bellows, and John F. Dillon as members. Three of the Commission's members were confirmed on 4 March. one of the other two, Mr. Bellows, resigned on 8 October prior to confirmation. Colonel Dillon, one of the three early confirmed, died on that day and

[20] Gleason L. Archer, "Radio and Big Business," the American Historical Society, Inc., New York, 1939, pp. 271–272.

the chairman, Rear Adm. Bullard, died of a heart attack on Thanksgiving Day of the same year. The organization meeting was held on 15 March 1927.[21]

The lack of understanding of the radio situation by most of our legislators is evidenced by the provision of this Radio Act of 1927 which envisioned that the licensing authority of the Commission would be returned to the Department of Commerce at the end of one year and thereafter the Commission would only act in an advisory and appellate capacity.[22] No engineering staff was provided to assist the members in their gigantic task. In order to provide such assistance, and to eliminate the chaotic conditions which were rendering naval radio communications on and near our coastlines practically impossible, the Navy Department volunteered the services of the Radio Division of the Bureau of Ships. This proffer was accepted.

The initial action taken by the Commission occurred on 17 April 1927 when it ordered 129 stations, which had been operating on unassigned frequencies, to return to the frequencies previously assigned them by the Department of Commerce.[23]

Having established the Commission, Congress immediately proceeded to make it a political football. Broadcasters sought more favored frequencies and enlisted the support of their Congressmen as well as their listeners. The latter were encouraged to write directly to the Commission as well as to their Congressmen imploring that the station of their choice be given most favorable consideration. The Commission was quickly buried under an avalanche of letters and affidavits. One station, alone, is purported to have filed 170,000 affidavits collected from its listeners.[24] Constant congressional pressure was brought to bear upon each member of the Commission. Lawrence F. Schmekebier stated, "Probably no quasijudicial body was ever subject to so much congressional pressure as the Federal Radio Commission. Much of this, moreover, came at a time when several members of the Commission had not been confirmed." [25]

Even under favorable conditions it is doubtful that the Commission could have executed its licensing responsibility within the alloted year. Faced with outside interference and loss of membership, it made slow progress and even that was subject to the most severe criticism. Congress, in March 1928, reluctantly extended the Radio Commission's authority for another year but curbed its authority by providing for five broadcasting zones and "a fair and equitable allocation among the different States thereof in proportion to population and area." [26] This amendment was subject to different interpretations by the several Commission members and hindered them in carrying out their responsibilities. This resulted in additional legislation being enacted in 1929 and thereafter such legislation became increasingly frequent.[27]

THE FOURTH INTERNATIONAL RADIO CONFERENCE

The Fourth International Radio Conference had been scheduled to convene during 1917 with the U.S. Government as host. World War I prevented this meeting. Following the conclusion of the war, the members of the Inter-Allied Radio Conference endeavored to convene this Conference at an early date. They established a Technical Committee to submit proposed redrafts of the London Convention of 1912 which would provide a new convention more in keeping with technological advances in radio. The U.S. Government agreed to cir-

[21] Ibid., p. 306.

[22] Ibid., p. 425.

[23] Ibid., p. 307.

[24] Ibid., pp. 306–307.

[25] "The Federal Radio Commission," service monograph of the U.S. Government No. 65, p. 55.

[26] Davis amendment to the Radio Act of 1928.

[27] Gleason L. Archer, "Radio and Big Business," the American Historical Company, Inc., New York, 1939, pp. 425–426.

culate these proposals through diplomatic channels to the numerous nations which were to be invited to the Conference in order that they might have at least 6 months to study them prior to the convening of the Conference. The initial deliberations of this Technical Committee coincided with the beginning of enormous technological improvements in radio equipment and with the commencement of radio broadcasting. The improvements were so rapid that the Technical Committee could not make the required changes and have them circulated and studied before these changes required modifications. This condition continued for several years and was further complicated by the development of the use of short waves and the concurrent expansion of the spectrum and an increase in international radio interference.

Finally, on 4 October 1927, a decade later than its original scheduling, the Conference was convened in Washington. Almost 300 delegates, from 79 countries, including those of several colonies and possessions which were authorized independent action, were participants. The primary purpose of the Conference was to formulate international regulations to minimize interference between radio stations engaged in international service or which were international in their capabilities of creating interference.[28]

The U.S. delegation of 15 members, appointed by President Coolidge, was headed by the Hon. Herbert Hoover, Secretary of the Department of Commerce. Capt. T. T. Craven, USN, Director of Naval Communications, was the Navy member. Capt. S. C. Hooper, Comdr. F. H. Roberts, Lt. Comdrs. W. S. Hogg, Jr., T. A. M. Craven, R. H. Blair, and L. Cooper and Lt. A. I. Price, all of the U.S. Navy, were designated technical advisors. Lt. Comdr. Tully Shelley, USN, was a member of the reception committee.[29]

The Conference was opened with a welcoming address by President Coolidge which was immediately followed by addresses by Secretary Hoover, Col. T. F. Purvis, chief of the British delegation, and Mr. G. J. Hotker, chief of the Netherlands delegation.[30] Conforming to international protocol Secretary Hoover was installed as the presiding officer of the Conference.

Secretary Hoover's address stressed the necessity of providing regulations which would not impede advances in the art or fetter the minds of persons who might be directed toward scientific discovery and technical improvement. He pointed out that the London Conference had to deal with but a few frequencies which concerned calling and communication channels for ships' use but that the present Conference must concern itself with the entire usable radio spectrum. He stated that the radiotelephone, broadcasting, direction finding, beacons, facsimile, aircraft, and the thousands of amateurs engaged in international communication, research, and experimentation had resulted in an enormous expansion of the original application of radio. He closed his address with a plea that the conferees endeavor to reach an international understanding to control these extended uses of radio.[31]

At the plenary session the following committees were established to facilitate and expedite the work of the conferees:

Committee for revision of the London Convention;
General Regulations Committee;
Mobile and Special Services Regulation Committee;
Point-to-point and Other Fixed Services Regulation Committee;
Tariff Committee;
Technical Committee;
Drafting Committee; and,
International Code of Signals Committee.

The United States proposed the use of both French and English and offered to provide the interpretors. This was agreed to by the Conference.[32]

[28] Proceedings of the Institute of Radio Engineers, 1928, W. D. Terrell, "The International Radio Telegraph Conference of Washington, 1927," p. 409.

[29] U. S. Naval Communication Division Bulletin No. 58, 18 Oct. 1927, p. 2.

[30] Ibid., p. 1.

[31] Ibid., pp. 1–2.

[32] Ibid., p. 2.

In some countries radio was a government or quasi-government monopoly while in others it was purely a commercial operation. Difficulties arose as to the legality of regulating the latter. On a motion of the United States, this was solved by dividing the regulations into two parts, General Regulations and Supplementary Regulations. Those regulations and rules of a managerial nature and relating to the operation of radio service were put in the Supplementary Regulations. These were not to be signed by the delegates of the United States and other countries where radio was a commercial venture. A provision making the regulations of the International Telegraph Convention, to which the United States was not a party, applicable to radio was included in the Supplementary Regulations.[33]

The Convention as accepted, contained 24 articles, couched in broad terms covering the licensing of transmitting stations and operators, the inviolability of the contents of messages, intercommunication between ship and ship, and ship and coastal stations, the settlement of commercial accounts, the establishment of an international radio consulting committee, the allocation of blocks of call letters by nations, and the settlement of disputes concerning radio matters by arbitration.[34]

The radio arbitration plan caused a rift to develop during a plenary session held on 19 November. Japan and Great Britain opposed the inclusion of this article which was strongly advocated by the delegations of the United States, Argentina, Mexico, and Uruguay. The motion in favor of the article was brought to vote after extensive debate and effort at compromise, and was carried. This was the first treaty to which the United States was a party which contained an unconditional, compulsory arbitration clause.[35]

The General Regulations contained 34 articles. The most important of these, article 5, dealt with the allocation of frequencies. Frequency was adopted as the standard of measurement, supplanting the less accurate means of specification by wavelength. Instead of making frequency allocations by countries, the Conference made allocation to specific services, all nations having equal rights to the uses of these specified bands. The allocations basically conformed to those established in the United States based upon the recommendations of its Third National Radio Conference. The band from 10 to 100 kc. was assigned to stations engaged in point-to-point service, chiefly transoceanic service. The band from 100 to 550 kc. was designated primarily for ship-to-ship, ship-to-shore, and aircraft services. This included radio beacons on a band at about 300 kc. and provided for a radio compass service on a band around 375 kc. The 500-kc. frequency remained the international calling and distress wave and could be used for message traffic only on condition that interference with call signals and distress signals would not result. The band between 194 and 285 kc. was one on which it was somewhat difficult to secure agreement. This difficulty arose because many of the European countries desired to utilize it for broadcasting. It was finally agreed that part of this band could be used for broadcasting in Europe only, and that the rest of the band would be assigned to mobile and aircraft services and to fixed stations not open to public correspondence. The band from 550 to 1500 kc. was universally recognized as the broadcasting band. One frequency in this band, 1365 kc. was assigned to small ships. The entire band could be used by mobile service in any part of the world on a noninterference basis. The band between 1500 to 60,000 kc. was divided into 40 smaller bands and ap-

[33] Institute of Radio Engineers, 1928, W. D. Terrell, "The International Radiotelegraph Conference of Washington, 1927," pp. 409-411, the Wireless Engineer. "The Washington International Radiotelegraphic Convention 1927," p. 667.

[34] Ibid. App. N contains extracts of this Convention.

[35] Washington Post, 20 Nov. 1927.

portioned between mobile services, communication between fixed stations, broadcasting, and amateur stations. This allocation of the short waves involved some changes from the Third National Radio Conference allocation, but had the advantage of giving some assurance that stations of a given type operating in this band would be able to continue their operation subject only to the adjustment of interference with other stations engaged in similar service.[36]

The Conference gave definite recognition to the amateur in international radio communication by allocating for amateur use four exclusive bands and two nonexclusive bands. This was accomplished by the efforts of the American delegation supported by the Canadian and New Zealand delegations. This provision gave amateurs greater assurance of making international contact one with another.[37]

Although the Conference recognized that the allocation of frequency bands to specific services was necessary to minimize interference, there was a corresponding desire to leave to each country, or to groups of countries in a certain region, as much freedom as possible in making assignments to stations which are not international in their effect. Freedom was left for the assignment of any frequency to any station which could not cause international interference.

It was recognized that it was inadvisable to write into the regulations definite provisions of a technical or engineering nature which might become obsolete during the next few years. Instead, general provisions calling for the maintenance of a high-technical standard were adopted. For example, article 4 of the General Regulations required that a station must maintain its authorized frequency as closely as the state of the art would permit, and its radiation must be kept as free as practicable from all emissions not essential to the authorized type of communication. The various nations were allowed to fix the allowable tolerance between the assigned and transmitted frequencies, and they agreed to take progressive advantage of technical improvements to reduce this tolerance. The width of the frequency band of a transmitter was required to be reasonably consistent with good current engineering practice for the type of emission.[38]

The conferees considered that definite dates must be set on which certain restrictions on the use of damped-wave transmitters would become effective. The regulations provided that no further installations of transmitters of this type would be installed at fixed or land stations and that, after 1 January 1930, such transmitters installed on ships should, at full power, use less than 300 watts measured at the input of the supply transformer. It was provided, however, that no restriction should be placed upon the means which an operator of a mobile station in distress could use in attracting or in indicating his position and obtaining assistance.[39] The use of existing damped-wave transmitters was to be discontinued by all land stations prior to 1 January 1935.

The Regulations annexed to the London Convention were applicable exclusively to ship-to-ship and ship-to-shore services. In the Washington Convention most of the Regulations were applicable to mobile service, including aircraft. Provisions were included covering the use of traffic frequencies, the necessary control of traffic by land stations, the routing of messages by mobile stations, and other related matters. The Regulations required absolute priority for distress calls and messages and traffic pertaining thereto. A radiotelephone distress call consisting of the spoken expression "May Day" was included in addition to the telegraphic signal "SOS." Provision was also made for the use of a special signal

[36] Institute of Radio Engineers, 1928, W. D. Terrell, "The International Radiotelegraphic Conference of Washington, 1927," p. 412.

[37] Ibid.

[38] "International Radiotelegraph Conference, and General and Supplementary Regulations Thereto," Washington, Government Printing Office, 1937.

[39] Ibid.

for setting into operation an apparatus to give an automatic alarm and to warn someone on a ship fitted with such an installation that a distress signal would follow. A safety signal, "TTT," was also established to be used as a preamble for messages concerning the safety of navigation or containing meterological warnings. Article 6 of the General Regulations covered the issuance of operator's certificates. These provisions differed but little from the existent requirement of the United States, except that a chief operator's license on a vessel of the first class could only be issued to persons who had a year's experience under a first-class license. Provisions were included designating the hours of service for ships with one or with two operators. Complete revised lists of abbreviations or operator's procedure signals were included. These were also made applicable to aircraft communications.[40]

Throughout their work, the delegates endeavored to keep before them the principle, enunciated by the presiding officer, that the conclusions of the Conference should be of such a nature as not to interfere with the development of the art. The regulations adopted were the absolute minimum necessary to maintain orderly communications. The Convention and annexed Regulations became effective on January 1, 1929 for all of the ratifying governments. The Governments of Spain, Egypt, and Holland volunteered to be host to the next Conference scheduled for 1932. The invitation of Spain was accepted.[41]

In this most important of all the international radio conferences, every effort was made by all of the delegates to secure the correct solution of the problems under discussion. The technical questions in particular were usually discussed, and the conclusions arrived at, from a technical rather than a nationalistic standpoint. The general attitude was one of cooperation and of realization that the problems should be solved on their merits.

The preliminary work of the U.S. delegation and their technical assistants was thorough and of the highest order. With an allocation plan, based on services, ready to lay before the conferees, the U.S. delegation was in a position to dominate the Conference. Our delegation was ably supported by the French and Italian delegations as well as by most of those of the Western Hemisphere. In the many committee and subcommittee meetings our delegates never failed to show unanimity of opinion and effort to obtain decisions which would eliminate interference and further the art. The Navy was an important factor in the matter of radiofrequency allocation, in furthering the interests of the amateurs, and in protecting the interests of commercial communications against unnecessary governmental controls.[42]

In his closing address, made on 25 November 1927, Secretary Hoover stated:

> It is a great honor to be able to congratulate the delegations and in fact the peoples of their countries on the successful issue of this Conference. That the representatives of 80 different governments, the largest international conference of history, have been able to sit together for a period of 7 weeks and, without any important disagreement, to reach a unanimous conclusion upon so highly a technical and so difficult a problem, is in itself, not only a sign of progressive capacity of the world to solve international problems, but it is a fine tribute to the character and spirit of the delegations from all these nations.

The effects of this Conference and other national developments during 1927 were ably summed by the Director of Naval Communications, Capt. T. T. Craven, USN. He stated that the Fourth International Conference provided an agreement which made international administrative conditions more stable; the Federal Radio Commission was making the Radio Act of 1927 effective; and that national policies were becoming more firmly established. As a result of these developments, radiofrequency allocations would be more stable than heretofore and permit the improve-

[40] Ibid.

[41] Ibid.

[42] U. S. Naval Communications Bulletin No. Sixty, 15 December 1927.

ment of radio communications equipment along definite lines. This would permit the more rapid advancement of the naval communications improvement program.[43]

The Navy willingly gave up the use of many frequencies in the successful endeavor to obtain allocations based on usage. The elimination of interference on their assigned frequencies far outweighed these losses. Basic exchanges were those of 75, 85 and 95 kc. for five frequencies between 400 and 485 kc. and 315 kc. for 355 kc. Other losses necessitated the rearrangement and sharing of frequencies by certain of the naval shore radio stations.[44]

The Washington Conference established the International Technical Consulting Committee on Radio Communications. The purpose of this body was to provide opinions and advice on technical questions of radio communications which might be submitted by adhering nations or private enterprises. This Committee, which met between International Radio Conferences, was limited to advising the International Berne Bureau of Telecommunications on questions studied. The Bureau transmitted these advices to participating nations and private enterprises concerned to provide a basis for determination of technical standards to be adopted in drafting succeeding conventions.

THE FIFTH INTERNATIONAL RADIO CONFERENCE

The Fifth International Radio Conference was held, as scheduled, in Madrid in 1932. For the first time it was held concurrently with the International Telegraph Conference. This Radio Conference was the least important of all those held. The work of the previous one had been so complete and the worldwide economic depression had resulted in the reduction in research capabilities and the resultant lack of progress in the art. The Conference was concerned primarily with further interference reduction, providing additional communication facilities for the rapidly expanding use of aircraft, making available additional broadcast channels in the European area where chaotic broadcast conditions existed, and in expanding the spectrum upward from 23,000 to 30,000 kc. This Conference also recognized the effectiveness of high-frequency communications for mobile marine stations and the resultant convention assigned specfiic high-frequency channels for this purpose in order to further reduce interference and to provide useful long-distance communication facilities.[45]

THE SIXTH INTERNATIONAL RADIO CONFERENCE

The Sixth International Radio Conference was held in Cairo, Egypt, with the opening session being held on 1 February, 1938. Prior to this Conference the need for regional considerations of common interests was recognized. In 1937 a conference of North American countries concerning the broadcast bands was held in Ottawa. Another conference of Western Hemisphere nations was held in Lima, Peru, to discuss aeronautical radio and, finally, one of all American countries was held in Havana to consider the Western Hemisphere position at the forthcoming conference. Similar regional conferences were held by the European nations.[46]

The United States delegation to the Cairo Conference was headed by Senator Wallace H. White of Maine. He was assisted by three other delegates, one each from the War and Navy Departments, and one from the Federal Communications Commission.[47]

[43] Ibid., p. 2.

[44] Ibid.

[45] Journal of American Society of Naval Engineers, vol. 51, no. 2, May 1939. "International Telecommunication Conferences," S. C. Hooper, pp. 159–160.

[46] Ibid., p. 159.

[47] The Federal Communications Commission, successor to the Federal Radio Commission was established as a permanent commission by act of Congress in 1934.

Capt. S. C. Hooper, USN, was a delegate.

The Cairo Conference was important because of the rapid increase in hemispheric and transoceanic aviation, the increased uses of high frequencies, and the uses of the newly developed portion of the radio spectrum between 30 and 300 mc.

The more important changes incorporated in the convention were:

Designation of radio channels for the world's seven main intercontinental air routes, including calling, safety, and service channels;

Requirement that aircraft flying maritime routes carry radio equipment capable of operating on the distress frequency of 500 kc.;

Widening high-frequency broadcast bands to 300 kc. and assignment of special bands for tropical regions;

Limiting the use of spark transmitters to three channels and making it unlawful to use such transmitters with an output in excess of 300 watts;

Limiting the frequency tolerance and decreasing bandwidth tables;

Allocation for service uses of bands between 30 and 300 mg.;

Narrowing of bandwidth assigned amateurs;

Provision of meteorological services for use of balloon-carried miniature transmitters;

Establishment of 5000 kc. as the dividing line between regional and international frequencies;

Slight improvements in operating regulations based upon experience; and,

Provision for holding regional radio conference.[48]

Prior to completing their work the conferees accepted the invitation of the government of Italy to hold the next Conference in Rome in 1942. This did not materialize because of World War II. Instead, the next International Radio Conference was held in Atlantic City following that war.

[48] Journal of American Society of Naval Engineers, vol. 51, no. 2, May 1939. "International Telecommunication Conferences," S. C. Hooper, pp. 169–175.

Appendix A. Chronology of Developments in Communications and Electronics

640 BC

Thales of Miletus noticed the phenomena of static electricity acquired by amber upon its being rubbed.

1600

William Gilbert first used the term "electric force" in his published volume "De Magnete." (England)

1630

Otto von Guerke developed the first frictional electric machine. (Germany)

1676

Olav Roemer discovered that light travels at a finite velocity. (Denmark)

1725

Stephen Gray discovered that electricity could be conducted as a current. (England)

1745

Pieter Van Musschenbroeck discovered the principle of the electrostatic condenser. This led to the invention of the Leyden jar. (Holland)

1749

Benjamin Franklin demonstrated that lightning is an electrical phenomena.

1776

The Continental Navy, forerunner of the U.S. Navy, was established. Ezek Hopkins was appointed Commander in Chief.

The Continental Congress issued naval signal instructions. They consisted of signals based upon the manipulation of sails and the positions from which flags were displayed.

1777

A squadron of Continental vessels, dispatched to intercept the British West Indian Fleet, was directed to develop and promulgate signals to assist in discovering the enemy and advising of his locations and strength.

1797

Captain Thomas Truxton, U.S. Navy, devised the first known American signal book using the numerary system, numeral pennants, and several repeater flags for signal displays. This signal book contained approximately 300 signals. Fog signals were made by gunfire. Night signals were made by lanterns and gunfire.

1800

William Herschel discovered the existence of infrared rays. (England)

1801

Sir Humphrey Davy exhibited an electric carbon arc light. (England)

1802

The U.S. Navy issued the Barron Signal Book, the work of Commodore John Barry, U.S. Navy, and Capt. James Barron, U.S. Navy. Basically, it was the same as the Truxton Signal Book, which it superseded, except that it was better organized.

1813

The first revision to the Barron Signal Book was promulgated to the U.S. Navy. Flags replaced pennants and shapes were added.

1815

As a result of slow communications, the Battle of New Orleans was fought 15 days after the signing of the Treaty of Ghent.

1819

Hans Christian Oersted discovered the magnetic properties of an electric current. (Denmark)

1820

Johann Schweigger invented the first practical galvanometer. (Germany)

James Bowman Lindsay conducted experiments in communications utilizing the conductive properties of water. (Scotland)

1821

Andre' M. Ampere propounded the relationship between electricity and magnetism. (France)

1824

The Secretary of the Navy assigned the responsibility for U.S. naval communications to the Board of Naval Commissioners.

1825

George Simon Ohm discovered the relationship between the flow of electric current, resistance, and voltage. (Germany)

Jean Francois Arago proposed that propagated sound waves be utilized to measure ocean depths. (Italy)

1827

Sir Charles Wheatstone developed an acoustic device for the amplification of weak sounds. (England)

1831

Michael Farraday developed electromagnetic induction formulae. (England) Joseph Henry demonstrated the principle of electromagnetic induction. Farraday published the results of his experiments a year earlier than Henry.

Joseph Henry discovered the properties of mutual inductance and self-induction. He also improved the electromagnet and constructed the first electrically operated bell.

1837

Samuel F. B. Morse made application for a U.S. patent for telegraph system. Sir Charles Wheatstone made application for an English patent on a similar system.

1838

Carl August von Steinheil discovered the use of the earth-return. (Germany)

Joseph Henry first produced high-frequency electric oscillations and discovered that a condenser discharge is oscillatory.

1841

Lt. Matthew Fontaine Maury, USN, appointed to command the U.S. Navy Depot of Charts and Instruments. In this capacity he instituted a program of taking exact measurements of ocean depths by naval vessels.

1842

Alexander Bain developed the basic principles of transmitting pictures by electrical means. (England)

1843

The U.S. Congress appropriated $30,000 for the erection of a telegraph line between Baltimore and Washington.

Samuel F. B. Morse, while experimenting with communication by conduction across water, concluded that electricity could be conducted by water without the use of wire.

Samuel F. B. Morse and Alfred N. Vail devised the Morse Code.

1844

Telegraph circuit between Baltimore and Washington placed in operation.

1847

The Rogers and Black Semaphore Dictionary was adopted by the U.S. Navy but the Barron Signal Book (U.S. Navy Signal Book) was retained for tactical purposes.

1849

After completing the development of an electric telegraph instrument utilizing an electromagnetic relay, John Walker Wilkins predicted that "telegraphing without wires might be a possibility." (England)

1851

The First International Telegraph Conference was held in Berlin, Germany. This Conference compiled the Continental Code using 11 letters of the Morse Code.

1853

A. H. L. Fizeau shunted a Leyden jar across the terminals of the interruptor of an induction coil, thereby increasing the width of the spark gap and the efficiency of the coil. (France)

1854

Lt. Matthew Fontaine Maury, USN, attempted to measure ocean depths by underwater explosion, but was unsuccessful because he did not use a direct connection between the ear and the sea.

1856

S. A. Varley patented an induction coil, forerunner of the alternating current transformer. (England)

1857

Leon Scott developed an instrument for recording sound. (France)

1858

First transatlantic telegraph cable was opened.

The U.S. Navy Signal Book was revised. The Bureau of Ordnance and Hydrography was assigned the responsibility for signals and ciphers.

1859

Julius Plucker observed cathode rays. (Germany)

1861

Philip Reis designed a make-and-break platinum contact microphone capable of transmitting musical sounds but not speech. (Germany)

Civil War began in U.S. and a revised signal book was issued to the U.S. Navy.

1862

The Bureau of Navigation was assigned the responsibility for signals and ciphers. The U.S. Navy was directed to adopt the U.S. Army wire telegraph system of signals.

1865

Heinrich Daniel Ruhmkorff designed a radically improved induction coil. (Germany)

Civil War ended in U.S.

1867

James Clerk Maxwell predicted the actions of electromagnetic waves. (Scotland)

1869

The U.S. Navy Signal Office was established. A new U.S. Navy Signal Book was issued.

The U.S. Naval Observatory, the Washington Fire Alarm Telegraphic Office, and the Washington Western Union office were connected by telegraph lines for the purpose of providing a nationwide exact time service from the Observatory. From this service originated the well-known phrase, "Naval Observatory Time."

1870

Von Bezold discovered that the oscillations set up by a condenser discharge were of varying frequencies which created mutual interferences. (Germany)

1872

The U.S. Navy Signal Office issued the first American edition of the International Signal Code to facilitate communications between the Navy and the merchant marine.

The first patent for a wireless communication system was issued in the United States to Dr. Mahlon Loomis of Washington, D.C. It was based upon a drawing illustrating how the setting up of "disturbances in the atmosphere would cause electric waves to travel through the atmosphere and ground."

1873

Joseph May discovered the photoelectric property of selenium. (Ireland)

1874

Karl Ferdinand Braun discovered that galena-copper pyrites and other metallic sulphides offered higher resistances to the passage of an electric current through them in one direction than in the opposite direction. (Germany)

1875

Alexander Graham Bell invented the telephone.

Thomas Alva Edison observed the phenomenon of "etheric force".

John Kerr discovered the polarizing property of a nitrobenzene solution subjected to high voltage. This lead to the development of the Kerr cell which was a vital component of early television projectors which utilized mechanical scanning systems. (Scotland)

The U.S. Navy experimented with electric lights for visual signaling purposes.

Lord Kelvin developed the first practicable pressure tube for measuring water depths of less than 100 fathoms.

1876

The U.S. Navy adopted the English Morse telegraphic code.

1877

Lt. W. N. Wood, USN, perfected a system of electric lights for transmission of the English Morse telegraphic code.

Thomas Alva Edison developed apparatus which gave the first audible reproduction of recorded sound.

Emile Berliner observed that the resistance of a loose contact varies with pressure and applied this to microphone design.

Thomas Alva Edison patented a telephone transmitter of the variable resistance amplifying type using a button of solid carbon as the resistance element.

1878

Sir William Crookes invented the Crookes tube and demonstrated the properties of cathode rays. (England)

David E. Hughes was among the early discoverers of the phenomena controlling the action of the coherer. In experiments made in developing an inertia transmitter, he utilized a steel needle in loose contact with a piece of coke. This was essentially a self-restoring coherer. (England)

The signaling method of Wood, devised in 1877, increased the U.S. Navy's range of flashing lights from 6 to 16 miles.

1880

Jacques and Pierre Curie discovered the piezoelectric effect of quartz crystals. (France)

Julius Elster and Hans Geitel experimented with glass bulbs, both vacuum and gas filled, which contained a metal plate and an electrically heated wire, and observed that electrified particles were radiated by the wire in all directions. (Germany)

1882

Professor Amos E. Dolbear was granted a U.S. patent for a wireless system.

1883

Edison discovered that an electric current can be made to pass through space between a hot filament and an adjacent metallic plate. This was later called "Edison Effect."

1884

Paul Nipkow was granted a German patent an a television scanning disc. (Germany)

1885

Sir Williams Preece transmitted telephonic speech over 1,000 feet by conduction. (England)

1886

Prof. Amos E. Dolbear was granted a patent on a wireless system which utilized two elevated metallic conductors.

Prof. Heinrich Hertz proved that electromagnetic waves could be transmitted through space at the speed of light. This confirmed Maxwell's Theory. He also demonstrated that these waves could be reflected and refracted.

Alternating current was utilized for the first time in the United States in a commerical lighting system.

1888

Lt. (later Rear-Adm.) Bradley A. Fiske, USN, conducted experiments in communications between ships by conduction.

1890

Prof. Edouard Branly developed the coherer. (France)

Julius Elster and Hans Geitel developed the first phototube. This was sensitive to both visible light and ultraviolet rays. (Germany)

The responsibility for signals, ciphers and signaling equipment was transferred to the Bureau of Equipment. The U.S. Navy Signal Office was abolished.

1891

Nikola Tesla was granted U.S. Patent 454,622 on the "Tesla Coil." This coil was designed to produce a current of very high potential and very high frequency. During the same year, while experimenting with high-frequency currents, he discovered the principle of the rotary magnetic field and applied it to the induction motor.

The Ardois system of signaling by lights was introduced in some squadrons of the U.S. Navy.

1892

Sir William Preece signaled between two points by a system which employed both induction and conduction. This resulted in the appointment of a royal commission to investigate the practicability of the use of his system for communication between lightships and shore. (England)

In a speech before the Royal Academy, Sir William Crookes commented upon electromagnetic waves: "Here is unfolded to us a new and astonishing world, one which is hard to conceive should contain no possibilities of transmitting and receiving intelligence." (England)

1895

Guglielmo Marconi transmitted and received his first radio signals. (Italy)

Captain Henry Jackson, Royal Navy, commenced radio experiments in the British Navy. (England)

Alexander S. Popoff reported he had transmitted and received radio signals a distance of 600 yards utilizing Hertz apparatus and a coherer. (Russia)

Emile Berliner obtained U.S. Patent 548,623 for a method of recording sound on a flat disc of hard rubber.

1896

Guglielmo Marconi transmitted and received radio signals over a distance of 2 miles. (England)

Capt. William Jackson, Royal Navy, was successful in establishing radio communication between two ships. (England)

1897

The Telephotos system of signaling by lights replaced the Ardois system in the U.S. Navy.

Radio messages were exchanged between Lavernock, South Wales, and the Island of Flatholm, a distance of 3½ miles. (England) (11 May)

The Wireless Telegraph Co. & Signal, Ltd., was incorporated. (England)

Marconi was granted U.S. Patent 586,193 on his radio system.

Marconi officially demonstrated the use of radio between ship and shore. Signals transmitted from San Bartolomeo were received on the Italian warship *San Martino* over a distance of 11 miles. (Italy) (20 July)

Marconi, embarked in a tugboat, received radio messages transmitted from the Isle of Wight, distant 18 miles. (England)

Karl Ferdinand Braun constructed the first cathode ray oscilloscope capable of scanning with an electric beam. (Germany)

1898

The Kingstown Regatta was reported by radio to a Dublin newspaper from the steamer *Flying Huntress.* (Ireland)

Lloyds established three radio stations, one on the northeast coast of Ireland, one on Rathlin Island Lighthouse and the other at Bally Castle. (England)

Upon the outbreak of war with Spain the Secretary of the Navy directed the establishment of a U.S. Coast Signal System on the Atlantic and gulf coasts. This system was the predecessor of the U.S. Naval Communication System.

U.S. cut cables landing in Philippines and Cuba.

M. I. Pupin granted U.S. Patent 713,045 covering an electrolytic detector. (1 Apr.)

Sir Oliver Lodge granted U. S. Patent 609,154 on method of radio tuning. (Aug.)

Marconi conducted radio communications between South Foreland Lighthouse and East Goodwin Sands Lightship, a distance of 12 miles. (England)

1899

Marconi communicated across the English Channel by radio. (England)

The French Navy installed radio equipment on a gunboat. (France)

The East Goodwin Sands Lightship flashed the first radio distress signal after being struck by the steamer *R. F. Mathews.* (England)

United States Army Signal Corps established radio communications between Fire Island and Fire Island Lightship, a distance of 12 miles.

Marconi radio equipment installed on H. M. S. *Alexandria, Europa* and *Juno* and used for the first time during maneuvers. Messages were exchanged for distances up to 75 miles. (England) (July)

The U.S. Weather Bureau compiled a complete report of the investigations made by Prof. Lucian Blake with an underwater bell and microphone in his endeavors to develop an underwater signal system which would provide warnings of dangers to navigation.

The first American radio company, the American Wireless Telephone & Telegraph Co., was incorporated. This company obtained the Dolbear patents. Harry Shoemaker and John Greenleaf Pickard were its radio engineers. (Sept.)

Marconi arrived in the United States to radio bulletins of the America Cup races to James Gordon Bennett's New York Herald. (11 Sept.)

The U.S. Navy, at the request of Rear Adm. R. B. Bradford, U.S. Navy, Chief of the Bureau of Equipment, appointed a board of four officers to witness and report on the operations of the Marconi equipment during the radio reporting of the America Cup races.

Unfavorable weather delayed the beginning of the America Cup races from late September to October. Meanwhile, Admiral Dewey, who was returning from Manila to the United States, in the U.S.S. *Olympia,* via the Suez Canal and the Atlantic, had notified the Navy Department that he would arrive in New York on 30 September. Marconi was persuaded to go to sea with his equipment, contact the U.S.S. *Olympia* and make radio reports of her progress. Dewey anticipated his arrival date by 2 days and arrived in New York harbor just as Marconi was departing.

During a naval parade, staged in honor of Dewey, the SS *Ponce,* carrying Marconi and his apparatus and Lt. J. B. Blish, USN, one of the observing board, was assigned a place in the parade. During the parade the first official U.S. Navy radio message, from Blish to the Navy Department, was transmitted by Marconi. (30 Sept.)

Marconi's radio reporting of the races was a complete success and he was invited to demonstrate his equipment to the U.S. Navy.

A U.S. Navy Wireless Telegraph Board was appointed to investigate and report on the Marconi equipment to be tested in the U.S.S. *New York, Massachusetts* and *Porter* and at Navesink Light.

First official radio message from a U.S. naval vessel transmitted from the U.S.S. *New York.* (2 Nov.)

U.S. Navy tests of Marconi equipment were completed. The Wireless Telegraph Board recommended that the system be given a trial by the U.S. Navy. (8 Nov.)

The Trans-Atlantic Times printed on the SS *St. Paul,* in which Marconi was a passenger returning to England, was first ship's paper to print news received by radio. Transmission of the news was from the Isle of Wight when the *St. Paul* was 56 miles distant. (15 Nov.)

Marconi Wireless Telegraph Co. of America organized. (22 Nov.)

The U.S. Navy offered to purchase 20 sets of Marconi equipment. Offer was countered by the Marconi interests with endeavors to enter into a lease agreement. This was refused and no further negotiations were conducted. The Navy then adopted a policy of watchful waiting.

1900

John Stone applied for a U.S. patent on a radio tuning device. (8 Feb.)

Marconi granted British patent for a tuned system of radio. (England) (26 Apr.)

William D. Duddell discovered that the electric arc could be made to generate high-frequency energy and succeeded in generating continuous oscillations of approximately 10,000 cycles per second. (England)

Nikola Tesla predicted radar.

Nikola Tesla granted a U.S. patent on control of distant objects by radio.

Prof. Reginald A. Fessenden, while in the employ of the U.S. Department of Agriculture, accomplished the first radio transmission and reception of speech.

The Wireless Telegraph and Signal, Ltd., was reorganized as the Marconi Wireless Telegraph Co., Ltd. (England)

Lt. Comdr. (later Rear Adm.) Bradley A. Fiske was granted a U.S. patent, underlying Tesla's, on the control of distant objects by radio. (23 Oct.)

Mr. A. J. Mundy and Prof. Elisha Gray conducted experiments with underwater sound.

1901

Emile Berliner developed a flat disk shellac composition record.

Commercial radio service established between the the main Hawaiian Islands. (Mar.)

The U.S. Navy continued its policy of watchful waiting of radio developments.

Marconi's basic U.S. patent reissued as No. 11,913.

Marconi, De Forest, and the American Wireless Telephone & Telegraph Co. participated in an attempt to report the America Cup races. The latter firm by creating intentional interference, prevented the transmissions of the other two participants from being received. (Sept.)

Comdr. F. M. Barber, USN (retired) recalled to active duty for the purpose of studying and reporting upon the development and use of radio equipment in Europe. (1 Oct.)

The Wireless Telegraph Co. of America (De Forest) organized.

St. Johns, Newfoundland received the letter "S" transmitted from Poldhu. This is considered to be the first reception of a transatlantic radio signal. (England) (12 Dec.)

The accomplishments of Mundy and Gray in developing an underwater sound system led to the formation of the Submarine Signal Co.

1902

The Chief of the Bureau of Equipment, Navy Department, recommended the U.S. Government take action to exercise control over radio stations.

U.S. Navy Department issued instructions for preparing the masts of naval vessels for fitting with radio antennas.

The De Forest Wireless Telegraph Co. was incorporated. It absorbed the Wireless Telegraph Co. of America. (Feb.)

The Consolidated Wireless Co. was incorporated and absorbed the American Wireless Telephone & Telegraph Co.

Marconi, embarked in the SS *Philadelphia,* recorded Poldhu's transmission up to a distance of 1,551 miles. (England)

The unsavory promotion of radio stocks began.

Cornelius D. Ehret applied for the first patent on frequency modulation. (10 Feb.)

The Navy Department directed Comdr. F. M. Barber, USN (retired), to purchase two complete radio sets from each of four European firms; Slaby-Arco and Braun-Siemans-Halske of Germany and Ducretet and Rochefort of France. (Mar.)

Kaiser Wilhelm of Germany, concerned with the monopolistic attitude of the Marconi interests, proposed holding an international radio conference.

U.S. Navy constructed radio stations at Annapolis, Md., and Washington, D.C., for testing and evaluating radio apparatus.

Lt. J. M. Hudgins, USN, and two assistants, Chief Electrician's Mates J. H. Bell and William C. Bean, were sent to Europe to study the equipments being purchased. (May)

Marconi introduced the magnetic detector. (England) He was granted four U.S. patents (884,986 through 884,989) on this device. (25 June)

Prof. R. A. Fessenden introduced the electrolytic detector.

The National Electric Signaling Co. was formed by two Pittsburg entrepreneurs, Messrs. Hay Walker and Thomas Given, for the purpose of developing Fessenden's patents into a complete and saleable system.

Stone Telephone & Telegraph Co. was incorporated to exploit the inventions of John Stone. Massie Wireless Telegraph Co. was formed under the direction of Mr. Walter Massie as both a manufacturing and operating organization.

The Chief of the Bureau of Equipment, U.S. Navy, stated that it was not necessary that transmitters and receivers be of the same manufacture to provide radio communications.

The Secretary of the Navy convened the Wireless Telegraph Board, Comdr. Conway H. Arnold, USN, senior member, to supervise trials and determine apparatus best suited to U.S. Navy requirements. (14 Aug.)

Navy Department requested the De Forest Wireless Telegraph Co. of America, the Fessenden interests and Nikola Tesla to submit bids for the provision of radio equipments.

Tests of European equipments conducted between Annapolis, Washington and U.S.S. *Prarie and Topeka.*

The Wireless Telegraph Board submitted an interim report which pointed out the superiority of the Slaby-Arco equipment. (3 Dec.)

The De Forest Wireless Telegraph Co. delivered two sets of equipment for test. Neither Fessenden nor Tesla submitted equipments.

1903

The International Wireless Co. was incorporated and absorbed the Consolidated Wireless Co. (Feb.)

The U.S. Navy contracted for 20 Slaby-Arco equipments. (27 Mar.)

The National Electric Signaling Co. (Fessenden) stated that no notification of Navy tests had been received by it.

Fessenden patented the "Barretter," an electrolytic detector. (5 May)

The Bureau of Equipment informed Fessenden of previous correspondence of which he claimed to be unaware. He was then again requested to submit bids, which was promptly done. Later, he proposed that he provide two sets at his company's expense for testing by the Navy Wireless Board. He was directed to contact the president of that Board.

Fessenden withdrew his offers to provide equipment for tests, claimed that his patents were being infringed and that American radio manufacturers were being discriminated against by the U.S. Navy.

Eight major ships of the U.S. Navy were fitted with radio. Five naval shore radio stations of the North Atlantic coast were placed in operation. (July)

The U.S. Navy used radio for tactical purposes for the first time during the fall maneuvers.

The First International Radio Conference convened in Berlin to draft a protocol for consideration by the participating governments as the basis of a future convention. One of the articles of the protocol required all coastal stations to accept radio messages regardless of system in which originated. The Marconi interests opposed this article. The U.S. delegates were the most active of all members. (Aug.)

The Bureau of Equipment ordered an additional 25 sets of Slaby-Arco equipment. (10 Sept.)

Marconi interests proposed providing equipment to the U.S. Navy for a fixed amount to be considered as "life rental" of equipment but refused to have the efficiency of its equipment judged by Navy tests.

The SS *Campania* began publishing first daily shipboard newspaper from information and news items provided by radio.

The Radio Division of the Bureau of Equipment was established under Lt. A. M. Beecher, USN.

A radio school was established at the Brooklyn Navy Yard to provide electrician's mates instruction in radio operation and maintenace.

De Forest was granted U.S. Patent 887,069 on a magnetic detector.

"Instructions for the Use of Wireless Telegraph Apparatus" were prepared by Lt. J. M. Hudgins, USN, and issued the service.

General Electric Co. constructed its first high-low frequency alternator based on specifications provided by Fessenden. This alternator had a frequency of 10 kc.

The American De Forest Wireless Telegraph Co. established. In another unsavory stock manipulation this company rented the De Forest Wireless Telegraph Co. for $500 per annum.

Rear Adm. G. A. Converse, USN, became Chief of the Bureau of Equipment.

Lt. J. M. Hudgins, USN, became Head of the Radio Division.

1904

The American De Forest Co. absorbed the International Wireless Co. and cancelled stock in the latter company which was valued at $500,000. (Jan.)

The London Times, using De Forest radio equipment, endeavored to provide first-hand news from the scene of action during Russo-Japanese hostilities.

The De Forest interests exhibited radio at St. Louis World's Fair.

Lt. J. L. Jayne, USN, became Head of the Radio Division.

Harry Shoemaker, formerly of the International Wireless Co. and John Firth, one of the original backers of De Forest, formed the International Telephone & Telegraph Construction Co.

In answer to Fessenden's claim that his patents were being infringed the Secretary of the Navy informed him that the Navy had no jurisdiction over infringement claims.

Fessenden agreed to provide the U.S. Navy with radio equipment for tests, but only under protest.

The Navy would not agree to test Fessenden's equipment unless the tests were conducted under the same conditions applied to other firms.

John W. Griggs, former Attorney General of the United States, became president of the Marconi Wireless Telegraph Co. of America. (28 Apr.)

Fessenden agreed to supply two complete radio stations at a cost of one dollar, each.

Rear Admiral Henry M. Manney, U.S. Navy, appointed Chief of the Bureau of Equipment.

President Theodore Roosevelt appointed an interdepartmental board to consider the use of radio by the U.S. Government. (24 June)

U.S. Navy requested bids from the American DeForest Wireless Telegraph Co. and the National Electric Signaling Co. for four guaranteed long-distance stations to be constructed at San Juan, Puerto Rico, Guantanamo Bay, Cuba, Key West, Fla., and the Canal Zone. Contract awarded to the De Forest Co. (June)

By this date 24 U.S. Naval vessels were fitted with radio and 19 naval shore radio stations had been established. (30 June)

The Interdepartmental Board (Roosevelt Board) recommended that the U.S. Navy assume responsibility for all Government radio except that required by the Army. The latter was not to interfere with the Navy's coastal radio system. (12 July)

American Marconi interests protested the Roosevelt Board's recommendations.

Marconi interests again endeavored to persuade the U.S. Navy to accept a Marconi monopoly of radio. This was firmed refused. During this period the Navy reiterated the opinion that no radio station should be allowed on the coasts of the United States which would not accept messages from any properly tuned ship's apparatus, regardless of equipment used.

President Roosevelt approved and directed implementation of the recommendations of the Interdepartmental Board. (29 July)

U.S. Navy commenced daily transmissions of time signals. (9 Aug.) From this date it continued to expand and improve this service and until 1927 it remained the sole agency in the world making radio transmissions of this vitally important "Aid to Navigation.")

U.S. Navy tested National Electric Signaling Co. equipment and although it did not meet the promises of Fessenden, three sets were purchased.

Lt. (later Rear Adm.) S. S. Robison, USN, became Head of the Radio Division.

"Instruction for the Transmission of Messages by Wireless Telegraphy, U.S. Navy, 1904" were issued. These superseded instruction issued in 1903.

The National Electric Signaling Co. protested the Government's actions in purchasing Slaby-Arco equipments, claiming that such action with the development of their system.

The U.S. Navy issued instructions for all radio-equipped naval vessels to transmit meteorological data to U.S. Weather Bureau not less than once daily. (Nov.)

Throughout the entire year Fessenden constantly berated the U.S. Navy with infringement claims and for redress in the matter of royalties.

Prof. John Ambrose Fleming applied for British patent on the two electrode tube. (England)

1905

The Navy Department and the Department of Commerce and Labor jointly drafted legislation for governmental supervision of commercial and amateur radio operations. This was strenuously opposed by American Marconi and National Electric Signaling Co. interests and was not transmitted to Congress. (Jan.)

Fessenden apparatus installed on three major men-of-war. In tests it failed to satisfactorily meet naval needs.

The U.S. Navy adopted the Continental Morse Code.

The harsh 60-cycle emissions of the early transmitters softened by U.S. naval personnel increasing the number of segments of the mercury turbine interrupters to provide a 500-cycle note.

American De Forest Wireless Telegraph Co. completed installation of equipment at the U.S. Naval Radio Station, Key West, Fla. (Mar.)

Fleming granted U.S. Patent No. 803,684 on the two-electrode tube as a detector. (19 Apr.)

Judge William K. Townsend, U.S. circuit court, rendered decision in favor of Marconi in a suit against De Forest for infringement of basic patents.

The Wireless Telegraph Board ceased to function. Thereafter decisions as to type of equipments purchased were made by the Radio Division.

A U.S. circuit court rendered decision in favor of National Electric Signaling Co. in suit against the American De Forest Wireless Telegraph Co. for infringement of Fessenden's patent on the electrolytic detector. (Oct.)

Tests of equipment provided by the Stone Telephone & Telegraph Co. completed and eight sets purchased by the Bureau of Equipment.

Based upon the operational success of the equipment of the Massie Wireless Telegraph Co. 10 sets of their equipment were purchased by the U.S. Navy.

The U.S. Navy purchased 21 sets of radio equipment manufactured by the International Telephone & Telegraph Construction Co.

The U.S. Navy issued the first "International Radio Call Sign Book."

American De Forest Wireless Telegraph Co. completed all the radio installations under its contract except the one at Guantanamo Bay, Cuba. (Dec.)

1906

U.S. Atlantic Fleet conducted exercises over large ocean areas in an endeavor to develop the strategical use of radio. These exercises were unsatisfactory because of short ranges of equipments and interference. The failure of these exercises caused senior naval officers to lose confidence in the reliability of this method of communications and set back its development for naval use for several years.

American De Forest Wireless Telegraph Co. completed the installation of equipment at U.S. Naval Radio Station, Guantanamo Bay, Cuba. (Mar.)

The first disaster use of naval radio followed the San Francisco earthquake. The U.S.S. *Chicago* provided the only reliable means of rapid communication between the city and the outside world.

The National Electric Signaling Co. protested Navy's purchase of electrolytic detectors from American De Forest Wireless Telegraph Co. claiming infringement. The Secretary of the Navy directed the purchasing authority to disregard the protest.

Fessenden addressed a letter to President Theodore Roosevelt in an attempt to have Secretary of the Navy Bonaparte removed from office. A copy of this letter bears Fessenden's notation. "No reply received."

Lt. Robison prepared the "Manual of Wireless Telegraphy for Use of Naval Electricians." With revisions, it served as a standard textbook on the subject for the next two decades.

Lt. Comdr. Cleland Davis, USN, became Head of the Radio Division.

Fessenden continued to berate the Navy because it did not purchase National Electric Signaling Co. equipment. The Navy advised him that the excellent merit he claimed for his equipment was not sustained and that his bids were entirely too high.

Direction finding equipment developed by John Stone Stone experimented with in the U.S.S. *Lebanon*. It was not successful because it necessitated swinging ship to obtain maximum signal intensity and because little was known of the deviation caused by closed electrical loops inherent in ship construction. (Sept.)

Amateur and commercial radio interferences in the Boston area prevented transmission of messages to President Roosevelt in the U.S.S. *Mayflower* off Cape Cod, Mass. As a result of this the President directed the commander in chief, U.S. Atlantic Fleet, Rear Adm. R. D. Evans, USN, to make recommendations for the control of radio transmissions.

Second International Radio Conference convened in Berlin. Twenty-seven sovereign powers were represented. The U.S. delegation was headed by Ambassador Charlemagne Towers and consisted additionally of Rear Adm. Henry M. Manney, USN, (retired), Brig. James Allen, USA, Mr. Henry Waterbury and Comdr. F. M. Barber, USN (retired). (3 Oct.)

De Forest applied for a U.S. patent on the three-element vacuum tube. (25 Oct.)

The convention adopted by the Second International Radio Conference required compulsory handling of messages originating from or destined to ships, the compulsory handling of distress messages and the establishement of an international bureau at Berne for providing exchange of information. The efforts of the U.S. delegation were instrumental in the adoption of the first two mentioned articles. (3 Nov.)

Max Wein devised a form of quenched gap for spark transmitters. (Germany)

General H. C. Dunwoody, USA (retired), discovered the rectifying properties of carborundum crystals.

John Greenleaf Pickard discovered the rectifying properties of silicon.

By the end of this year many ships and shore radio stations of the U.S. Navy were fitted with composite radio equipments (transmitters and receivers of different manufacture).

Fessenden transmitted speech from Brant Rock, Mass., which was received at Macrahanish, Scotland. He utilized a 500-cycle spark transmitter. (Nov.)

The American De Forest Wireless Telegraph Co. obtained the controlling interest in and absorbed the International Telephone & Telegraph Construction Co.

United Wireless Telegraph Co. was organized by Abraham White (Schwartz). The assets of the American De Forest Wireless Telegraph Co. were transferred to the new company and De Forest was ousted, receiving $500 for his patents, excluding the three-element tube.

The General Electric Co. built a high-power low-frequency alternator (80 kc.).

Fessenden transmitted music and speech from Brant Rock, Mass., by means of the 80-kc. alternator provided by the General Electric Co. These transmissions were received by ships off the Virginia coast. (24 Dec.)

The Stone Telephone & Telegraph Co. became insolvent.

1907

De Forest applied for a U.S. patent on the three-element tube.

De Forest obtained rights to John Stone Stone's tuned circuit patent.

De Forest Radio Telephone Co. incorporated.

Christopher Columbus Wilson ousted Abraham White from the United Wireless Co. and intensified the stock-peddling policy of the company.

The U.S. Navy commenced transmitting hydrographic bulletins containing "Notices of Dangers to Mariners." (7 Aug.)

De Forest radio telephone equipment tested in U.S.S. *Connecticut* and *Virginia*. (Sept.)

The U.S. Navy contracted for 26 sets of De Forest radio telephone equipment for installation on ships of the "Great White Fleet" prior to their departure on their "Around the World Cruise." (Nov.)

Arthur Korn transmitted a picture by landline from Berlin to Paris. (Germany)

Boris Rosing and A. A. Campbell-Swinton separately and at about the same time published treatises on electrical transmission of pictures using electromagnetic scanning. (Russia-England)

Crystal detectors came into general use, replacing electrolytic detectors and coherers.

De Forest demonstrated radiotelephony between a ferry of the Lackawanna Railroad Co. and their Hoboken and New York City terminals.

1908

While in port at Rio de Janeiro, Brazil, U.S.S. *Ohio* broadcast music by radio.

The Marconi interests began limited and unreliable commercial radio service between Glace Bay, Nova Scotia and Clifden, Ireland. (England)

De Forest granted U.S. Patent No. 879, 532, on the three-element vacuum tube. (8 Feb.)

Rear Adm. R. D. Evans, USN, directed dismantling De Forest radio telephone equipments installed in "Great White Fleet" because they were being used improperly and because they interfered with normal radio communications. U.S.S. Ohio was allowed to retain its installation for experimental purposes. (Mar.)

The first Alaskan radio expedition erected and placed in operation the U.S. Naval Station, Cordova, Alaska.

The U.S.S. *Connecticut* en route from Hawaii to New Zealand, exchanged messages with U.S. Naval Radio Station, Point Loma, Calif., at a distance of 2,900 miles.

The Bureau of Navigation promulgated a revision of the "U.S. Navy General Signal Book, 1898," which consisted of three parts: General Signals, which included a telegraphic dictionary; Tactical Signals; and, Boat Signals. The use of the first-mentioned section was restricted to commissioned officers.

A 20-kc. alternator with a power output of 2,500 watts was constructed by the General Electric Co.

Poulsen developed an arc transmitter, the transmissions of which were received 150 miles away. (Denmark)

The U.S. Navy purchased two arc transmitters and receivers from Poulsen of Denmark.

The U.S. Senate failed to ratify the Berlin Convention of 1906.

The U.S. Naval Radio Research Laboratory established under the direction of Dr. L. W. Austin.

The first U.S. Navy civilian radio expert, George H. Clark, appointed. He was assigned duties as an assistant to Dr. Austin of the U.S. Naval Radio Research Laboratory and to the Head of the Radio Division, Bureau of Equipment. (Aug.)

The U.S. Naval Radio Research Laboratory conducted experiments with the Poulsen arc transmitter and "tikker receiver" and recommended against their use because of the inadequacy of the receiver. This delayed the U.S. Navy's adoption of continuous wave transmission for approximately 4 years.

1909

The SS *Republic* collided with SS *Florida* off New York. Radioed calls for assistance resulted in keeping the loss of lives down to six persons and created such an impression upon the public that radio soon became looked upon as a seagoing necessity.

The House Committee on Merchant Marine and Fisheries favorably reported on a bill that would have required certain oceangoing vessels to be fitted with radio equipment manned by a capable operator. Congress failed to enact it into law. (Feb.)

The U.S. Navy contracted with the National Electric Signaling Co. for delivery of one 100-kw. synchronous rotary spark transmitter for installation in a shore radio station and two 10-kw. sets of the same type for installation in the U.S.S. *Salem* and *Birmingham*. The contract required that the shore station transmission be received, day or night by a ship distant 3,000 miles and that the ship transmitters would cover a minimum distance of 1,000 miles by day or night. (May)

Senator Frye introduced a bill into Senate requiring certain oceangoing vessels to be equipped with radio. (9 June)

Portable radio apparatus successfully service tested in the U.S. Atlantic Fleet.

The quenched spark gap, which energized the antenna circuit one or two impulses and then electrically opened the antenna circuit allowing the antenna to continue to oscillate at its own frequency, introduced in U.S. Navy in transmitters purchased from the Telefunken Co.

Tests of the Fessenden 100-kw. transmitter installed at Brant Rock, Mass. and the 10-kw. transmitters in U.S.S. *Salem* and *Birmingham* were unsatisfactory. (Dec.)

Congressman Roberts introduced a bill in the House which provided for the creation of a board of seven members, one each from the War, Navy and Treasury Departments, three from commercial interests and one unbiased scientist, to prepare, within 30 days of its organization, a comprehensive plan to govern the operation of all radio stations under the jurisdiction of the United States, giving due regard to all.

1910

The Roberts Bill reported out favorably by the House Committee on Naval Affairs.

Public Law 262 (Frye Bill), "The Radio Ship Act of 1910," passed the Senate and House and was approved to become effective on 1 July 1911. No further action was taken on the Roberts Bill.

Congress enacted legislation providing that in the future, the owner of any invention covered by a U.S. patent might recover reasonable compensation from the Government whenever their patents might be used by the Government without their consent.

Lt. Comdr. (later Rear Adm.) D. W. Todd, USN, relieved Lt. Comdr. Cleland Davis, USN, as Head of the Radio Division.

The Bureau of Equipment was dissolved, and the responsibility for radio was assigned to the Bureau of Steam Engineering. Rear Adm. H. I. Cone, USN, was the first Chief of this Bureau. (30 June)

Further tests of Fessenden 100-kw. and 10-kw. transmitters were conducted by the Navy. They failed to meet contract requirements.

1911

R. A. Fessenden was dismissed from National Electric Signaling Co. He brought suit for breach of contract and was awarded damages amounting to $400,000. This forced the company into receivership. Prior to this, Fessenden had developed the heterodyne method of radio reception. He utilized a small arc transmitter to generate the local oscillations.

The Radio Ship Act of 1910 became effective. The Radio Division of the Department of Commerce and Labor was established to enforce this law.

Lack of Government supervision of radio activities resulted in increased chaotic conditions as Government, commercial, and amateur operators vied for use. Transmissions of vituperations, frivolities, and obscenities exceeded the time used for legitmate messages. The Department of Commerce and Labor could not legally cope with the situation.

The Federal Telegraph Co. of Calif., was incorporated. It owned the U.S. rights to the Poulsen arc transmitter patents. (July)

The Navy issued its first radiofrequency plan.

De Forest's Radio Telephone Co. instituted a plea of bankruptcy. De Forest obtained employment with the Federal Telegraph Co. of Calif.

The Alaskan radio expedition established temporary U.S. naval radio stations at Kodiak, Dutch Harbor, and St. Paul.

The "Rules for Autumn Practice, 1911" required the use of radio for the tactical maneuvering of the U.S. Atlantic Fleet during battle practice.

The U.S. Atlantic Fleet was unsuccessful in carrying out the radio provisions required by "Rules for Autumn Practice, 1911." As as result of this, it was recommended and approved that a radio officer be assigned the staff of the commander in chief, U.S. Atlantic Fleet. (Oct.)

Adm. A. G. Winterhalter, USN, in the U.S.S. *Washington,* conducted experiments in ranging, using radio and sound. The latter included transmissions in air and under water. This was the first attempt to determine position acoustically, and indicated the vagaries of sound in air and proved the greater reliability of underwater sound.

1912

F. A. Kolster developed a decremeter for the measurement of radiofrequencies.

Submarine bell warning systems, developed by the Submarine Signal Co., had been installed at dangerous points of navigation along the coasts of the United States, Canada, the British Isles, France, Portugal, Italy, Brazil, Chile, and China. Numerous shipowners installed listening devices to receive the signals of these warning bells.

The Marconi interests purchased the Bellini-Tosi patents, including those on direction finders. (England)

Dr. Irving Langmuir developed a high-vacuum electronic tube to provide a pure electron discharge.

Dr. H. D. Arnold concurred with Langmuir in the necessity of having a high vacuum in an electronic tube. He believed that the instability of the existent three-element tubes was caused by the ionization of enclosed gases.

The U.S. Navy began providing postgraduate radio instruction for officers. Ens. (later Capt.) C. H. Maddox, USN, was registered at the Graduate School of Applied Science, Harvard University, whete he studied under Prof. G. W. Pierce, one of the country's foremost radio engineers. (Feb.)

The British Government, which had extended the United States an invitation to attend the Third International Radio Conference, withdrew its invitation because of our failure to ratify the Berlin Convention.

The U.S. Senate ratified the Berlin Convention of 1906. This ratification was ably supported by Rear Adm. John R. Edwards, USN. (3 Apr.)

Radio aided in reducing the loss of life in the S.S. *Titanic* disaster. This disaster indicated the necessity of maintaining a continuous radio watch at sea. (14 Apr.)

The U.S. Navy was directed to use the term "radio" in lieu of "wireless."

The U.S. Navy began experimenting with the use of radio in submarines. Communications were established off Newport, R.I., at a distance of 4 miles.

The Institute of Radio Engineers was formed by combining the Society of Wireless Telegraph Engineers and the Wireless Institute. Robert H. Marriott, a civilian radio expert in the employ of the Navy, was its first presiding officer. (13 May)

The Third International Radio Conference convened in London. The American delegation was headed by Rear Adm. John R. Edwards, USN. Other naval members were Lt. Comdr. D. W. Todd, USN, and Dr. L. W. Austin. (4 June)

The temporary naval radio station, Kodiak, Alaska, was struck by lightning and destroyed.

Construction was commenced on the naval radio station, Radio (Arlington), Virginia.

The United Wireless Telegraph Co. was adjudged guilty of infringing Marconi patents. As a result, a bankruptcy petition was filed. Their assets, which included 400 ship installations and 17 shore radio stations, were acquired by Marconi interests.

The Office of Superintendent of Naval Radio

Service was established under the Chief of the Bureau of Navigation for the purpose of operating and administrating Government radio stations. Material and budgetary functions remained the responsibility of the Bureau of Steam Engineering. Capt. (later Rear Adm.) W. H. G. Bullard, USN, was assigned duty as the first superintendent.

The Third International Radio Conference adopted a Convention which included regulations pertaining to safety of life at sea, most of which had been proposed by the U.S. delegation. (5 July)

The U.S. Government extended an invitation to hold the Fourth International Radio Conference in Washington in 1917.

Naval radio stations were opened to commercial traffic in all areas where commercial radio facilities were nonexistent or inadequate.

Naval radio stations were modernized. The Wireless Apparatus Co.'s IP76 double-banked receivers, using Pickard's perikon detectors, were provided.

R. A. Fessenden joined the staff of the Submarine Signal Co.

The Radio Ship Act of 1910 was amended to require certain seagoing vessels to carry two operators, to install an adequate source of auxilliary power for radio equipment, and to extend its provisions to cover shipping on the Great Lakes.

The Alaskan radio expedition of 1912, under command of Lt. E. H. Dodd, USN, established naval radio stations at Unalaga, St. George, Kodiak, and Cordova, and refitted the stations at St. Paul and Dutch Harbor.

The Bourne bill was introduced in the Senate to provide legislation necessary for the Government to control the activities of commercial and amateur radio stations.

S. 5334, a substitute for the Bourne bill, which reduced governmental authority and defined the controls over commercial and amateurs stations was introduced. This bill was supported by Government officials, with Lt. Comdr. (later Rear Adm.) D. W. Todd, USN, as their spokesman, and was perfunctorily opposed by commercial and amateur interests.

The Navy experimented with radio in aircraft, under the direction of Ens. (later Capt.) C. H. Maddox, USN, and succeeded in establishing communication, from a height of 300 feet, with the U.S.S. *Stringham* over a distance of 6,000 yards. The same aircraft also made contact with the U.S.S. *Bailey* and the naval radio station, Annapolis, Md.

Congress passed S. 5334 and it became Public Law 264. (13 Aug.)

Lt. (later Rear Adm.) Stanford C. Hooper, USN, was assigned duty on the staff of the Commander in Chief, U.S. Atlantic Fleet as Fleet Radio Officer. This was the first time that an officer had been designated specifically to advise a fleet commander on matters pertaining to radio. (16 Aug.)

Congress appropriated funds for the erection of high-powered naval radio stations in the Canal Zone, on the west coast, in the Hawaiian Islands, American Samoa, Guam, and the Phillipines.

All battleships, flagships of cruiser and gunboat divisions, and destroyer flotilla leaders were directed to appoint radio officers.

Hooper succeeded in firmly establishing discipline and exercising control of radio circuits of the Atlantic Fleet.

The Fessenden 100-kw. synchronous rotary spark transmitter was installed at the U.S. Naval Radio Station, Radio (Arlington), Virginia. (Dec.)

The Federal Telegraph Co. installed a Poulsen 30-kw. arc transmitter at the U.S. Naval Radio Station, Radio (Arlington), Virginia, for comparative tests with the Fessenden 100-kw. synchronous rotary-gap spark transmitter.

Radio competition was established between ships of the U.S. Atlantic Fleet.

Public Law 264 became effective. (13 Dec.)

The Tropical Radio Co., subsidiary of the United Fruit Co., purchased the controlling interest in the Wireless Specialty Apparatus Co.

De Forest and several of the officers of the defunct Radio Telephone Co. were charged with using the mails to defraud, and were tried by the Federal Government. De Forest was acquitted.

De Forest discovered that increased signal implification could be obtained by connecting three-element tubes in cascade.

John Hays Hammond, Jr., developed an automatic course stabilization device and a means of security of its control by radio.

The Commander in Chief, U.S. Atlantic Fleet, issued to his command a scouting cipher of the transposition type.

George Clark and Guy Hill, U.S. Navy civilian radio experts, developed a quick frequency changer for radio transmitters.

Tests conducted with the 30-kw. Poulsen arc transmitter indicated the possibility of its being superior to the 100-kw. synchronous rotary-spark transmitter.

1913

The continued failure of radio equipment manufacturers to meet Navy specifications for ruggedness and reliability resulted in a Bureau of Steam Engineering decision to design and manufacture its own radio equipment.

The Navy obtained rights to the Cohen capacity coupled receiver circuit and employed Dr. Louis Cohen as a consultant in receiver design. Additional radio engineers were employed, and the various navy yards were made responsible for the design and manufacture of specific components. (Feb.)

The U.S. Naval Radio Station, Radio (Arlington), Virginia, was commissioned. (13 Feb.)

Lt. Comdr. (later Adm.) A. J. Hepburn, USN, relieved Lt. Comdr. D. W. Todd, USN, as Head of the Radio Division.

Lee DeForest formed the Radio Telephone & Telegraph Co.

The United States and France cooperated using radio stations at Radio (Arlington), Virginia, and Eiffel Tower, Paris, to make longitude determinations and to procure data for comparing velocity of electromagnetic and light waves.

The Navy Department issued the confidential registered "Battle Signal Book" of the U.S. Navy, 1913, which followed the same format as the "General Signal Book, U.S. Navy, 1908."

Acceptance tests of the Fessenden 100-kw. synchronous rotary-spark transmitter conducted between the U.S.S. *Salem* and U.S. Naval Radio Station, Radio (Arlington), Virginia, proved the superiority of the 30-kw. Poulsen arc transmitter and Fessenden's heterodyne method of reception. The Fessenden 100-kw. transmitter failed to meet contract guarantees. (May)

De Forest discovered that the three-element tube could be used as an oscillator.

Sound equipment was installed in one division of battleships of the Navy for experimental signaling purposes. Perfect signaling was carried on by this method with the division at anchor. When the method was tested with the division underway, the ship generated noises which interfered to the extent that further tests were abandoned.

The Bureau of Steam Engineering stated its policy concerning radio patents, ". . . it could not take cognizance of patents. It must have certain apparatus and must go on buying it from whomever can or will supply it until it is informed by the Department of justice or some other authority that we must stop it." However, Navy contracts for radio equipment continued to carry a clause requiring supplying firms to protect the Government against patent infringement actions. (20 May)

Difficulty in communicating with U.S. Atlantic Fleet units off Veracruz, Mexico, pointed out the inadequacy of the naval radio system from a military standpoint and the lack of security of transmitted information.

A revision to the 1913 "Battle Signal Book" was issued which provided for enciphering code groups.

Edwin H. Armstrong filed patent application on the regenerative circuit. (29 Oct.)

Radio received major consideration at the Safety at Sea Conference held in London. (12 Nov.)

Ten three-element vacuum tube amplifiers were purchased by the U.S. Navy from the DeForest Radio Telephone & Telegraph Co.

The U.S. Navy accepted the 100-kw. Fessenden transmitter, settlement being effected by compromise.

Bellini-Tosi direction finder equipment was installed and tested in the U.S.S. *Wyoming* with disappointing results. It was removed and installed at Cape Cod, Mass. for further tests ashore.

1914

The Service Radio Code of the U.S. Navy was promulgated for the use of radio operators. It was not intended as a security system but was used as such during the Veracruz incident. (10 Feb.)

De Forest filed application for a U.S. patent on a feedback circuit similar to one filed by Armstrong 5 months earlier. (Mar.)

De Forest exhibited a radio receiver developed by him which utilized a three-element vacuum tube as an oscillator. This could be used to provide the locally generated continuous waves required for heterodyne receiving. (Apr.)

The Naval Radio Station, Darien, C.Z., fitted with a 100-kw. arc transmitter, was commissioned. This was the first station of the high-powered chain. (1 July)

German men-of-war off Veracruz, notified of England's entrance into World War I by an apparently innocuous commercial message, managed to put to sea before the British commander became aware of the situation. (2 Aug.)

President Wilson issued a proclamation which prohibited the handling of messages on nonneutral character by radio stations within the jurisdiction of the United States. The Secretary of the Navy was made responsible for its enforcement, and he delegated this responsibility to the Superintendent of the Naval Radio Service. (5 Aug.)

The Marconi Wireless Telegraph Co. of America questioned the validity of censorship instructions placed into effect by the Navy. (12 Aug.)

The Marconi Wireless Telegraph Co. of America radio station at Siasconsett, Mass., ignored censorship and rendered nonneutral service to a British cruiser. The station was closed by the Navy. (Sept.)

Hooper was ordered to Europe as an observer of radio usage in the war zone.

The high-powered radio station at Tuckerton, N.J., ownership of which was disputed between belligerent nationals, was taken over and operated by the Navy, at the direction of the President. (9 Sept.)

The Navy tested the Hammond system of remote radio control of moving objects.

A 30-kw. arc transmitter was installed at the radio station operated by the Navy at Tuckerton, N.J.

The Secretary of the Navy convened a board to review naval communications requirements and to make recommendations to bring the Naval Radio Service up to a satisfactory state-of-war readiness. (6 Dec.)

The Radio Test Shop, Washington Navy Yard, was charged with the task of originating means of and developing apparatus for radio reception.

The Radio Test Shop, Washington Navy Yard, redesigned the De Forest audiofrequency amplifiers and began manufacture of two-stage amplifiers, designated SE 1000.

R. A. Fessenden of the Submarine Signal Co.

developed an underwater oscillator which served both as a transmitter and receiver. He patented the method in the belief that signals emitted by the oscillator and reflected by submerged objects could be used to measure distance.

The first cross-licensing agreement of U.S. radio patents was consummated between Marconi interests and the National Electric Signaling Co. the Marconi interests paid the latter almost $300,000 in royalties for previous infringements. This reflected their failure to maintain adequate research and to maintain their equipments up to date.

The Radio Telephone & Telegraph Co. (De Forest) sold radio rights to the three-element tube to the American Telephone & Telegraph Co. for $90,000. De Forest retained limited rights to manufacture tubes for amateur and experimental purposes. Arnold and Langmuir completed its development and application as a repeater for long-distance telephony.

1915

Hooper completed his duty as radio observer in Europe and returned to the United States under orders as the Head of the Radio Division, Bureau of Steam Engineering.

Mr. Hiram Percy Maxim organized the amateur radio association, the American Radio Relay League. (Jan.)

Congress authorized an additional half million dollars for the construction of high-powered naval radio stations. (3 Mar.)

Hooper became Head of the Radio Division, Bureau of Steam Engineering. (Apr.)

The British Marconi Co. opened negotiations with the General Electric Co. for the exclusive use of the Alexanderson alternator. These negotiations failed because of the wartime pressure on British foreign exchange. (May)

The American Telephone & Telegraph Co. began tests of long-distance radio voice communications from Radio (Arlington), Virginia, with the cooperation of the Naval Radio Service. (15 June)

The Navy obtained the American Telephone & Telegraph Co.'s method of providing a feedback circuit to make an associated vacuum tube oscillate. This method was incorporated in receivers being designed at the Washington Navy Yard.

Navy receivers, Types A (60-600 kc), B (30-300 kc., and C (1200–3000 kc.) were designed by Dr. Louis Cohen with the assistance of Messrs. George C. Clark and L. C. Butts and placed in production at the Washington Navy Yard.

The German-owned and unlicensed station at Sayville, Long Island, suspected of rendering nonneutral service, was taken over by the Navy for the purpose of providing an additional transatlantic radio circuit. (9 July)

Voice communications transmitted by the American Telephone & Telegraph Co. from Radio (Arlington), Virginia, were received at Darien, C.Z., Mare Island, Honolulu and Paris. (Oct.)

The Marconi Wireless Telegraph Co. of America sought an injunction against Emil J. Simon to prevent his use of the Marconi four-circuit tuning patent in equipment sold by him to the Navy. Simon contended that the Government was liable under the act of 5 June 1910. His contention was upheld.

The Naval Consulting Board of the United States was organized under the chairmanship of Mr. Thomas Alva Edison. (2 Oct.)

The U.S. States Department refused to assist the American Marconi Wireless Telegraph Co. in their efforts to obtain concessions from South American countries for the purpose of extending radio communications to those countries. (4 Nov.)

Navy Type A 1917, receiver was designed by the Radio Test Shop, Washington Navy Yard.

Dr. Peter Cooper Hewitt and Mr. Elmer A. Sperry commenced developing a gyro-stabilization system for pilotless flying bombs. The cost of this development became excessive, and upon their request the Naval Consulting Board of the United States gave the project favorable consideration.

The Navy commenced broadcasting hydrographic and meteorological bulletins, covering west coast waters, from U.S. Naval Radio Station, Mare Island, Calif.

Thirty kw. arc transmitters were installed at naval radio stations at Boston, Mass.; Guantanamo Bay, Cuba; Great Lakes, Ill.; San Juan, P.R.; and Cordova, Alaska.

Congress established the Chief of Naval Operations as the senior military command over all Navy activities. Cognizance of the operations of the Naval Radio Service was transferred from the Bureau of Navigation to the Chief of Naval Operations. Maintenance and budgetary responsibility remained with the Chief of the Bureau of Steam Engineering.

Dr. F. A. Kolster of the Bureau of Standards developed a rotating coil direction finder.

1916

The Superintendent of Naval Radio Service took the initial step in organizing the U.S. Naval Communication Reserve. Members of the American Radio Relay League and commercial operators formed the nucleus of this organization.

Two sets of Bellini-Tosi radio direction finder equipment were purchased under guarantee from the Marconi Wireless Telegraph Co. of America. The tests were unsatisfactory and the equipments were returned to the contractor.

Mr. William Dubilier submitted mica condensers to the Navy for test. These proved unsatisfactory but resulted in the Navy drawing up specifications for a condenser of this type. Dubilier was successful in meeting these specifications.

The Navy began using the world's first remote radio receiving and transmitter control station, in the old State, War, and Navy Building, Washington.

The U.S. Naval Radio Station, Chollas Heights (San Diego), Calif., equipped with a 200-kw. arc transmitter, was commissioned. (1 May)

A 48-hour mobilization of U.S. communications began, with the cooperation of the American Telephone & Telegraph Co. Using combined radio and landlines the Captain of the U.S.S. *New Hampshire,* off the Virginia Capes, conducted two-way conversations with the Secretary of the Navy in Washington and the Commandant of the Navy Yard at Mare Island, Calif. (6 May)

The Navy purchased two experimental radiotelephone equipments from the Western Electric Co. for installation in battleships. They provided satisfactory two-way telephone communications up to the distances of 30 miles, but were deemed undesirable because they utilized the same frequencies as regular radio communication.

The Navy secured exclusive rights to the Kolster radio direction finder patents for a period of 2 years.

The British radio direction finder network detected the sortie of the German Fleet from Wilhelmshaven to the North Sea. This enabled the British Grand Fleet to meet and engage them at the Battle of Jutland. (30 May)

The Fortifications Appropriation Bill provided funds for tests of and for the exclusive procurement of the Hammond system of remote radio control.

U.S. Naval General Order 236 directed the establishment of the Naval Communication Service headed by a director under the Chief of Naval Operations. Capt. (later Rear Adm. W. H. G. Bullard, USN, was the first director. (28 July)

The League Island Navy Yard, Philadelphia, Pa., was directed to manufacture 30 direction finders of the Kolster type and to conduct experiments for developing this apparatus for fitting into aircraft.

The Naval Aircraft Radio Laboratory was established at Pensacola, Fla., for the purpose of testing, developing, and fitting aircraft radio equipment.

A joint Army-Navy Board was established to supervise the tests of the Hammond system of radio control. The Navy members were Capt. John A. Hoogerwerff, Comdr. David W. Todd, and Lt. Joseph Ogan, USN. (25 Aug.)

The U.S. Navy in cooperation with the French Government completed the determination of the difference in longitude between Paris and Washington by radio. Measured in terms of time, with a probable accuracy within 0.01 second, this was 5 hours, 17 minutes and 35.67 seconds.

Lt. T. S. Wilkinson, USN, witnessed tests of an aircraft controlled by a Sperry stabilization and course-keeping system. His report stated that the aircraft could not be controlled with the degree of accuracy required to hit a moving target and recommended that the Army might find it useful against military targets.

Decision was rendered that both Marconi and De Forest interests infringed each other in the manufacture of three-element tubes.

U.S. Navy commissioned its new high-powered radio station at Pearl Harbor, Territory of Hawaii. This station was equipped with a 300-kw, arc transmitter. (1 Oct.)

Navy Type B, 1917 receiver was designed.

Congress appropriated funds for the construction of the Naval Research Laboratory.

Transpacific commercial radio circuit was opened to traffic. (5 Nov.)

De Forest experimental station was opened at Highbridge, N.Y., and broadcasted election bulletins which were received within a radius of 200 miles.

Station at New Rochelle, N.Y. operated by Messrs. Charles V. Logwood and George C. Cannon commenced broadcasting music one hour daily, except Sunday. (Nov.)

U.S. Department of Commerce held informal hearings on an Interdepartmental Radio Committee draft of legislation which materially increased governmental control over radio. It was opposed by the Marconi interests. (21 Nov.)

The Navy installed a 60-kw. arc transmitter at Radio (Arlington), Virginia, which had been removed from the Tuckerton radio station.

Personnel of the Radio Division, Bureau of Steam Engineering, investigated the underground antenna system of Dr. J. H. Rogers, and noted the increase in the ratio between signal and noise and the better directivity of the system.

U.S. Navy commissioned its new high-powered radio station at Cavite, P.I. It was equipped with a 300-kw. arc transmitter. This completed the construction of the high-powered chain. (19 Dec.)

Secretary of the Navy, Josephus Daniels, openly advocated the elimination of commercial interests from ship-shore radio operations.

Twelve radio direction finder equipments were placed under construction for installation along the Atlantic seaboard.

Navy receivers, Types A, B, and C were installed in ships and shore radio stations.

The Navy began standardization of radio components by assignment of type numbers.

1917

Hearings on proposed Interdepartmental radio legislation, which had been introduced in the House by Congressman Alexander, began before the House Committee on Merchant Marine and Fisheries.

Three sets of reliable radiotelephone equipment, employing frequencies above those normally used for naval radio communications and capable of providing nine simultaneous voice channels, were purchased from the Western Electric Co. and installed in battleships.

Class 4, U.S. Naval Reserve was created. This was the official beginning of the U.S. Naval Communications Reserve.

The Bureau of Steam Engineering contracted with the Western Electric Co. for 15 sets of radiotelephone transceivers for experimental purpose in connection with the submarine chaser program. This equipment was assigned the Navy type number CW 936 and was the forerunner of the modern vacuum tube transmitter.

Lt. A. Hoyt Taylor, USNR, district communication officer, Ninth Naval District, was directed to establish a temporary laboratory and conduct investigations of submerged antenna systems. From these it was determined that antennas submerged in fresh water gave signals 10 times stronger than those of the same type laid underground; that these submerged antenna were periodic and could be utilized for multiple reception; and that an antenna of length equal to one-eighth of a wavelength gave the best response.

The Naval Consulting Board of the United States established a Special Problems Committee. Because of the German submarine menace a subcommittee of this Committee was established to conduct research on submarine detection by sound.

The Submarine Signal Co. proffered its complete facilities to assist the Navy in the development of submarine sound detection systems. This offer was accepted. (28 Feb.)

A comprehensive system of landlines connecting local activities with Naval District Headquarters and connecting the latter with the Navy Department was leased, to make available more frequencies for mobile and transatlantic uses and to reduce interference with those uses.

The General Electric Co. and the Western Electric Co. agreed to work with the Submarine Signal Co. in the development of submarine sound detection systems. The latter company agreed to make a study of the disturbances given off by submarines and other disturbances of a similar nature which might be encountered.

Navy types SE 95 (300–3000 kc.) and SE 143 (100–100 kc.) receivers were designed under the direction of Lt. W. A. Eaton, USN, with the consultant services of Prof. L. A. Hazeltine, developer of the neutrodyne method of radio reception.

At this time over 25 percent of the radio equipment of the U.S. Navy was of naval design. (1 Apr.)

An underwater sound experimental station staffed by personnel of the Submarine Signal Co., the General Electric Co., and the Western Electri Co. was established at Nahant, Mass.

Shortly after 1 p.m., simultaneously with the President's signing the resolution declaring the existence of a state of war with Germany, the U.S. Naval Communication System broadcasted to the world that the United States had entered World War I. (6 Apr.)

All amateur and commercial radio stations were either closed or taken over by the Navy. (7 Apr.)

An Alexanderson 50-kw. alternator was installed in the former Marconi stations at New Brunswick, N.J. The original purpose of this installation was to compare it with the Marconi timed-spark transmitter.

Three-element vacuum tubes manufactured by De Forest Co. were so inferior in quality that about 90 per cent of an order for 2,000 were rejected.

The Secretary of the Navy, Josephus Daniels, appointed a board of naval officers for the purpose of procuring suitable apparatus for conducting both offensive and defensive operations against submarines. This board, known as the Special Board on Antisubmarine Devices, was provided with the services of several consultants experienced in underwater sound. (11 May)

The Secretary of the Navy approved the recommendation of the Naval Consulting Board of the United States, which recommended that the Navy conduct experimental work on automatically controlled aircraft, carrying explosives, capable of being catapulted, and thereafter controlled by radio from the ground or a remotely flying airplane. (22 May)

Dr. L. W. Austin, Director, Naval Radio Research Laboratory, devised an antenna system which made it possible to obtain unidirectional bearings with a radio direction finder.

Prewar differences in operating missions resulted in the U.S. and Royal Navies having incompatible radio equipments. The Royal Navy had highly selective but insensitive receivers, while the U.S. Navy receivers were the exact opposite. This necessitated the installation of British equipment in many U.S. men-of-war operating with the British Grand Fleet.

Lack of security consciousness and failure to develop satisfactory codes and ciphers made it necessary for the U.S. Navy to adopt Allied (British) security systems during the war.

The National Research Council convened a meeting of Allied scientists for the purpose of discussing all previously developed means of detection of underwater sounds. (1 June)

The Special Board on Antisubmarine Devices was organized, and plans were drawn up for the coordination of all activities concerning underwater sound detection. Acting upon a recommendation of the National Research Council, additional groups of scientists were formed, each group being assigned research in specified areas of underwater sound detection.

The NCB, Mark I cipher box, designed by Lt. Comdr. (later Rear Adm.) Russel Wilson, USN, was issued to the naval service.

The Pan-American Radio Co. was formed by the British and American Marconi companies and the Federal Telegraph Co. for the purpose of exploiting radio communications in South American countries.

Comdr. B. B. McCormick, USN, reported as

Naval Inspector of Ordnance at the plant of the Sperry Gyroscope Co., to provide naval supervision over a contract with that company to develop naval seaplanes into pilotless missiles. (15 June)

Lt. Comdr. H. P. LeClair, USN, became Head of the Radio Division, Bureau of Steam Engineering.

Messrs. Given and Walker organized the International Signal Co., to which they transferred the patent assets of the National Electric Signaling Co.

Prof. M. Mason proposed the development of the MV-tube underwater sound detection equipment.

The Director of Naval Communications was assigned additional duty as Chief Cable Censor. (26 July)

Schools for the training of radiomen were established at Harvard University, Cambridge, Mass., and Navy Yard, Mare Island, Calif. The two schools had a combined capacity for training 5,000 men.

The Allied Transatlantic Communication Conference held in New London, Conn., decided to augment radio communications between the United States and Europe by constructing two additional high-powered stations in the United States and one in France.

The New London group of scientists which had been conducting research in binaural methods of submarine sound detection, was augmented and redesignated the Naval Experimental Station. This station was assigned the additional function of service testing all development of underwater sound sound detection equipment.

The Navy Department requested the General Electric Co. to provide a higher powered alternator for the transmitting station at New Brunswick, N.J. They replied that a 200-kw. alternator would be available by 1 January 1918. (1 Oct.)

Lt. A. Hoyt Taylor was assigned duty as Transatlantic Communication Officer in command of the reactivated former Marconi receiving station at Belmar, N.J. He was directed to utilize the information gained by his underwater underground experiments to improve the efficiency of transatlantic reception.

Lt. E. H. Loftin, District Communication Officer, Eighth Naval District, was directed to utilize the knowledge obtained by Taylor for the purpose of duplexing the Naval Radio Station, New Orleans, La., without locating the transmitters remote from receiving equipment.

The Code and Signal Section became a branch of the Naval Communications System. (Dec.)

Numerous acoustical devices were developed for underwater sound detection, none of which were too reliable. All required either to be towed or to have the detecting vessel stop in order to listen. However, most of the U.S. Navy destroyers and submarine chasers were equipped with listening equipment, mostly of the MV-tube type.

1918

Naval Aircraft Laboratory was moved from Pensacola, Fla., to the Naval Air Station, Hampton Roads, Va. (1 Jan.)

President Wilson's Fourteen Points were broadcast by the New Brunswick, N.J., station and were received at the German station at Nauen. (8 Jan.)

The Director Naval Communications was made responsible for the collection and dissemination of information about movements of ships. (10 Jan.)

The Navy purchased the German-owned radio patents seized by the Alien Enemy Property Custodian.

The Marconi Wireless Telegraph Co. of America advised the Navy Department of the plans of the Pan-American Radio Co. for developing radio communications in South American countries. Assurances were given by the Head of the Radio Division, Bureau of Steam Engineering, that the Secretary of the Navy understood and would not interfere with the proposed plans.

The Bureau of Yards and Docks was assigned the responsibility of providing and maintaining local telephone facilities with naval yards and stations, and for providing lines and facilites for connecting them to the nearest commercial exchange. The Naval Communications Service was made responsible for provision of long lines and the operation and administration of all telephone facilities.

The U.S. Supreme Court reversed a decision of September 1915, which had held the Government liable for patent infringement of equipment purchased by it. (4 Mar.)

The first successful flight of a pilotless aircraft was achieved. It was launched by the impulse-type catapult, after which it climbed steadily and flew in a straight line for 1,000 yards, at which distance the automatic distance gear was set to cut the throttle.

Assistant Secretary of the Navy, Franklin D. Roosevelt, issued the so-called "Farragut Letter," accepting certain responsibilities on the part of the Government for the protection of contractors against patent infringement suits. (29 Mar.)

The amateur station of Ens. (later Lt.) A. Fabbri, USNR, at Bar Harbor, Mane, was leased by the Navy for use as a transatlantic receiver station. Because of its location it proved the most efficient station for this purpose. It was equipped with a "blind-end" loop antenna system designed by Mr. E. A. Proctor of the Wireless Specialty Apparatus Co.

The Navy acquired the patents of the Federal Telegraph Co. and their three high-power and five coastal radio stations for $1,600,000. (15 May)

Mr. Carl L. Norden was directed to construct two flywheel-powered catapults for the purpose of launching pilotless flying missiles.

Construction of the Lafayette transmitter station at Croix dé Hins, France, was commenced by the U.S. Navy. (28 May)

Sites were selected for installation of radio direction finder stations at the entrances to the principal U.S. Atlantic seaports.

The Navy installed the General Electric 200-kw. Alexanderson alternator at the Naval Radio Station, New Brunswick, N.J., making it the world's most powerful transmitting station. (June)

Two transatlantic cables were severed by the Germans 60 miles east of Sandy Hook, N.J. (4 June)

A 200-kw. arc transmitter was placed in service at the transmitting station at Sayville, Long Island.

Congress enacted legislation, clarifying the act of 25 June 1910, making the Government responsible to patent owners in the event it manufactured or procured equipment infringing patents. (1 July)

After completing arrangements with several South American countries, the Pan-American Co. discovered that the Secretary of the Navy was determined to use a naval radio station at the U.S. terminal of South American radio circuits. No further effort was made at the time by that company to establish these circuits.

Receiving of transatlantic circuits was centered at Bar Harbor, Maine, from where traffic was automatically relayed to Washington where the messages were copied. All transmitters on transatlantic circuits were keyed from Washington beginning at this time.

A site was selected at Monroe, N.C., for a high-powered transmitting station.

Cmdr. S. C. Hooper, USN, became Head of the Radio and Sound Division, Bureau of Steam Engineering. (Aug.)

Dr. L. W. Austin, Director of the Naval Radio Research Laboratory, developed several balanced circuits, one of which could be used for the simultaneous reception of signals from several different transmitting stations provided they used separated frequencies.

The Hammond system of radio control was demonstrated in Hampton Roads, Va. In these demonstrations the steering functions, the engines, and mine-setting operations of a moving surface vessel were controlled from a shore station and from an aeroplane. (23 Aug.)

A hydrophone school was established at New London, Conn., to train officers in the installation and maintenance of underwater sound detection equipment.

Lt. Comdr. A. Hoyt Taylor became the Director of the Naval Aircraft Radio Laboratory. (Sept.)

The Naval Radio Station, Annapolis, Md., was commissioned. It was equipped with a 300-kw. arc transmitter. (Sept.)

President Wilson's address launching the Fourth Liberty Loan campaign was broadcast from New Brunswick, N.J., and receipted for by the German station at Nauen. (17 Sept.)

A successful launching of a pilotless aircraft was made but lack of ruggedness and instability of the plane caused it to crash. (23 Sept.)

The German Government transmitted from Nauen, addressed to the Director, Naval Communications, its acceptance of Allied terms for an armistice. This was received in Washington and immediately delivered to the White House. (12 Oct.)

The successful launching of a pilotless aircraft was followed by sustained flight at 4,000 feet about two degrees off the preset course. The distance mechanism, set for about 7 miles, failed to function and the plane flew out of sight to the eastward over the Atlantic. (17 Oct.)

Norden recommended better designed planes, and a redesigning of the automatic control system to permit carry a human check pilot during further development of pilotless aircraft.

The Naval Aircraft Radio Laboratory was moved from Hampton Roads, Va., to the Naval Air Station, Anacostia, D.C.

The joint board reporting on the Hammond tests on 23 August stated that he had not demonstrated control of a submerged carrier (torpedo).

A contract was signed for two 1,000-kw. transmitters to be installed in the transmitting station at Monroe, N.C. (1 Nov.)

The Navy purchased all shipboard and shore station installations of the Marconi Wireless Telegraph Co. of America for the U.S. Government except those used for transoceanic communications.

An armistice was signed with the German Government. (11 Nov.)

The construction of the Lafayette transmitting station was halted. (1 Dec.)

The proposal to construct a high-powered transmitting station at Monroe, N.C., was abandoned.

Representative Alexander introduced a resolution in Congress which proposed giving the Navy Department exclusive ownership of all present and future commercial radio stations in the United States.

Three radio direction finder stations were established around the entrance to New York Harbor and began coordinated operations to provide fixes for vessels in that vicinity. (26 Dec.)

The Navy experimented with low-frequency underwater reception and discovered that a submarine could receive high-powered transmissions over long distances when submerged to a depth of 21 feet.

The first air navigation range system was installed by the Navy.

With the exception of the Navy Experimental Station, New London, Conn., all the underwater sound detection groups and training schools established during the war were abolished. Dr. H. C. Hayes became the head of the remaining activity which was considerably decreased in size and limited in functions.

1919

The vigorous opposition of commercial interests resulting in the House Merchant Marine Committee unanimously tabling the Alexander Resolution. See page 527.

The Radio Test Shop designed the SE 1420 (40–1250 kc.) receiver. This was thoroughly shielded and was the first radio receiver built with an amplifier as an integral part of the set.

Reception of transatlantic signals were sufficiently reliable to permit closing the Belmar, N.J., receiver station.

The Marconi interests renewed their efforts to procure exclusive use of the Alexanderson alternator. This was opposed by the Navy and Comdr. S. C. Hooper, USN, was successful in delaying the consummation of this transaction. (2 Feb.)

The Fortification Appropriation Act provided funds for further demonstrations and possible purchase of the Hammond system of remote radio control torpedoes or other underwater carriers of high explosives. (3 Mar.)

Rear Adm. W. H. G. Bullard, USN, again became Director of Naval Communications. (31 Mar.)

Dr. H. C. Hayes discovered that the MV-tube set could be used for measuring the angle of reflection of transmitted signals echoed from the ocean floor. This permitted its use as a depth finder.

A conference between General Electric Co. officials Bullard and Hooper, resulted in the decision by the former to discontinue negotiation with the Marconi interests for the sale of Alexanderson alternators. (18 Apr.)

General Electric Co. officials reached the decision to establish an international communication system. provided the support of the U.S. Government could be obtained to provided them a monopoly in this field. Navy officials agreed to endeavor to obtain the desired support and aided in drafting a proposed charter for the new company.

The Secretary of the Navy directed that action on the proposed charter giving the General Electric Co. a monopoly of radio communications in the United States be held in abeyance.

Construction of the Lafayette transmiting station was resumed. (4 May)

Owen D Young suggested that the officials of the Marconi Wireless Telegraph Co. of America and the Pan-American Radio Co. join with the General Electric Co. in forming an American-controlled radio operating company.

A flight of three U.S. Navy NC planes departed Trepassey, Newfoundland, on a transatlantic flight. They were fitted with radio equipment especially configured to the planes. (16 May)

The Navy plane NC–4 arrived at Horta, Fayal, Azores. The other planes made forced landings short of the Azores; one sank, and other other made Ponta Delgado but proceeded no further. Radio communications were maintained with U.S. Naval radio stations or with ships stationed along the path of the flight for the entire trip. (17 May)

The NC–4, arrived at Lisbon, Portugal. Lt. Comdr. A. C. Reed, USN, completing the first Atlantic crossing by an airplane. Due to compass casualty the flight from the Azores to Portugal was made possible only by homing on the destroyers stationed along the plane's path with the direction finder. Ens. H. C. Rodd, USNR, acted as radio operator of the NC–4. (27 May)

The pilotless aircraft missile program was moved to the Naval Proving Ground, Dahlgren, Va., under the supervision of Capt. T. T. Craven, USN, with Mr. Carl L. Norden as consultant. (27 May)

The Secretary of the Navy deferred decision to enlist Government aid in support of an American-controlled radio operating company.

General Electric Co. officials reached the decision to form an American operating company, free of foreign control, with or without obtaining a Government monopoly.

The sole remaining supporter of Government ownership of United States radio stations was Secretary of the Navy Josephus Daniels. (1 July)

During fiscal year 1919, the U.S. Naval Communication System, exclusive of fleet communications, handled 1,189,120 dispatches containing text amounting to 71,347,860 groups.

The first Presidential radio broadcast was made by President Wilson returning from France in the U.S.S. *George Washington*. His address to the crew was indistinctly received on the northeastern seaboard on 2380 kc. (4 July)

The President, by Executive order, directed the Navy to return commercially owned radio stations as of midnight, 29 February 1920. (1 July)

The Secretary of the Navy transmitted to Congress the text of a proposed bill which would authorize the Navy to use its stations for commercial traffic.

The Secretary of the Navy transmitted a proposal to Congress recommending that ship-shore and transocean radio circuits be made a Government monopoly under the Navy and that all naval radio stations be opened to commercial and press traffic.

Mr. E. J. Nally of the Marconi Wireless Telegraph Co. of America and Mr. A. G. Davis of the General Electric Co. were sent to England to purchase British-owned interests in the Marconi Wireless Telegraph Co. of America.

The U.S.S. *Ohio* was assigned to the Bureau of Engineering as an experimental ship for the development of new radio equipments and installations.

The General Electric Co. obtained the controlling interest in the Marconi Wireless Telegraph Co. of America by the purchase of 364,826 shares of stock.

The Navy laid a radio-piloting cable in Ambrose Channel at the entrance to New York Harbor.

The U.S.S. *Semmes* conducted tests of the radio-piloting cable laid in Ambrose Channel. It was demonstrated that such a system could be used to permit navigation in restricted waters during periods of low visibility. Following the tests the project was turned over to the Department of Commerce, which took no further action. (6–9 Oct.)

The Radio Corp. of America was incorporated. The articles of incorporation prohibited the election of a director or officer who was not a citizen of the United States and allowed such participation by the Government in the administration of its affairs as the directors might deem advisable. Not more than 20 percent of the stock could be owned and voted by aliens. Mr. Owen D Young was elected chairman of the board of directors, Mr. E. J. Nally, president and Mr. David Sarnoff, managing director. (17 Oct.)

Norden recommended the pilotless-aircraft missile project be expanded to include the use of obsolete planes as antiaircraft targets (drones).

The Radio Corp. of America began operations. The Marconi Wireless Telegraph Co. of America ceased operations. (20 Nov.)

The General Electric Co. and the Radio Corp. of America signed a cross-licensing agreement. The latter company was prohibited from manufacturing radio equipment but became the sales agent for General Electric radio equipment. (20 Nov.)

The joint Army-Navy Radio Control Board recommended that the proper naval weapon using the Hammond system of radio control should be a standard naval torpedo with an added midsection to house the radio control equipment.

The Radio Test Shop, Washington Navy Yard, designed the SE 1440 receiver for use with direction finding equipment. It was the first receiver in which the audiofrequency amplifying circuit was an integral part. Following this, the same facility designed multiple-stage amplifiers, consisting of three stages of radiofrequency amplification followed by a detector stage and then two stages of audiofrequency amplification, in order to provide the necessary amplification for aircraft reception and direction finding.

The Bureau of Steam Engineering made the decision to make no further purchase of arc or spark equipments and to concentrate on the development of satisfactory vacuum tube transmitters.

The Navy developed an antenna sleet melting system for installation in its stations in subfreezing areas.

The Navy first established air-to-ground voice communications by radio.

By the end of 1919 the U.S. Navy was equipped with receiving equipment vastly superior to that of other navies or commercial users.

The commercial companies, seeing no future requirements for vacuum tube transmitters, refused to continue their development. Late in the year, the Bureau of Steam Engineering decided to expend a quarter of a million dollars to continue development of this type of transmitter.

A fleet communication plan, entitled "The Force Tune System" was developed and adopted. This required an increase in shipboard radio installations and simultaneous reception and transmission.

1920

The Bureau of Steam Engineering addressed similar letters to the American Telephone & Telegraph Co. and the General Electric Co. requesting they make some arrangement between themselves which would permit the manufacture and further development of the three-element tube. (5 Jan.)

Following the request of the directors of the Radio Corp. of America that a naval officer above the rank of captain be appointed to attend their meetings to present the Government's views, Rear Adm. W. H. G. Bullard, USN, Director of Naval Communications, was assigned this additional duty by direction of President Wilson. (14 Jan.)

The Bureau of Steam Engineering resorted to temporary improved installations of existing radio receiving equipments which were given the designation models E, F and R. Models E and F included an acceptor-rejector circuit. To reduce interference, the motor buzzer set was adopted as a substitute for the spark gap for low-powered transmissions.

In anticipation of a satisfactory patent cross-licensing agreement between three-element tube manufacturers, and in an effort to standardize and obtain improved tubes at a lower cost, the Bureau of Steam Engineering convened a conference of naval radio engineers and commercial manufacturer's representatives. (30 Jan.)

The U.S.S. *Breckinridge* ran a line of sonic soundings from Charleston, S.C., to Key West, Fla., using the MV-tube equipment and Hayes' angle of reflection method.

Contracts were made with the General Electric Co. for 20 model TC transmitters for battleships and 15 model TD transmitters for naval air stations. Another contract was made with the Western Electric Co. for 20 model TB voice modulated transmitters for installation in battleships for gunfire control communication.

The Navy returned the commercially owned radio stations, taken over at the beginning of the war, to the Radio Corp. of America, which resumed commercial operations of them on the same day. (1 Mar.)

The U.S.S. *Ohio* was assigned the tasks of developing improved and below deck radio installations in ships; improvements in and multiple use of antennas; service tests of new equipments; and development of a remote radio control system for surface ships.

The Westinghouse Electric and Manufacturing Co. purchased a controlling interest in the Fessenden radio patents. (22 May)

The title of the Bureau of Steam Engineering was changed to Bureau of Engineering. (4 June)

Congress authorized the use of naval radio stations for 2 years for the handling of commercial traffic and press on a noncompetitive basis with commercial enterprises.

Armstrong was granted U.S. Patent 1,342,885 on the superheterodyne receiver. (8 June)

A Navy plane was successful in homing on the radio transmissions of a battleship at a distance of 160 miles. (16 June)

The Naval Radio Laboratory, Anacostia, D.C., began scheduled radio broadcasting.

The American Telephone & Telegraph Co. became a corporate partner of the General Electric Co. in ownership of the Radio Corp. of America. The two companies signed a cross-license agreement which made it possible to manufacture and improve the three-element tube. (1 July)

The Westinghouse Electric & Manufacturing Co. and the Navy signed cross-license agreements on radio patents.

The Westinghouse Electric & Manufacturing Co. purchased the Armstrong regenerative and superheterodyne radio patents. (5 Oct.)

The Lafayette transmitting station, equipped with two 1,000 kw. arc transmitters, was completed and turned over to the French Government. (15 Nov.)

The Navy made a successful launching and flight of a pilotless aircraft missile utilizing a special designed plane. (18 Nov.)

Comdr. S. C. Hooper, USN, addressed a letter to Owen D Young, chairman of the board of directors, Radio Corp. of America, pointing out that officials of that company were thwarting efforts of radio manufacturers to provide vacuum tubes to the public. (11 Dec.)

Construction of the Naval Research Laboratory, Anacostia, D.C., was commenced.

The Navy experimented with voice communications by radio between aircraft and a partially submerged submarine and was successful in establishing communications.

1921

The Federal Telegraph Co. negotiated a contract with the Government of China for the erection of transpacific radio stations in that country. (8 Jan.)

The Radio Corp. of America objected to the establishment of a transpacific circuit by the Federal Telegraph Co. and suggested that such a circuit be operated by a consortium of all powers which had wrangled radio concessions from China. Since this was not consistent with our open door policy, Young then suggested that the Radio Corp. own and operate the U.S. terminal and the Federal Co. operate the Chinese terminal.

The Secretary of the Navy approved the recommendations of a board appointed to investigate and report on the feasibility of the remote control of aircraft by radio. This board had recommended that this project should be undertaken and placed under the cognizance of the Bureau of Ordnance.

The Interdepartmental Radio Board convened to adjudicate patent infrigement claims against the Government. Navy members were Comdr. S. C. Hooper and Lt. Comdr. E. H. Loftin. The latter was appointed chairman. (12 Feb.)

Loftin in his work with the Interdepartmental Radio Board stated: "There was not a single company among these making radio sets for the Navy which possessed basic patents sufficient to enable them to supply, without infringement, a complete transmitter or receiver."

The Chief of the Bureau of Engineering addressed similar letters to the General Electric and American Telephone & Telegraph Co. criticizing them for failure to provide three-element tubes for the merchant marine. (23 Apr.)

The Chief of the Bureau of Ordnance notified the Chief of Naval Operations of his intention to discontinue efforts to develop a pilotless flying missile. (27 Apr.)

A contract was issued the General Electric Co. for the Model TE transmitter configured for submarines, the Model TF for submarine tenders, and the Model TH for general service usage.

The Interdepartmental Radio Board recommended the U.S. Government make infringement award to patent owners in the amount of $2,869-700.27. $1,819,520.69 of this sum was apportioned against the Navy. (31 May)

The U.S.S. *Iowa* was fitted for remote radio control and the U.S.S. *Ohio* was equipped with remote radio control equipment.

The U.S.S. *Iowa,* under radio control of personnel in the U.S.S. *Ohio,* was used as an aircraft bombing target. Only two direct hits were made by the U.S. Army Air Force and these did little damage. (22 June)

The Westinghouse Electric & Manufacturing Co. became a corporate partner in the Radio Corp. of America with the privilege of manufacturing 40 percent of the radio equipment sold by that corporation. (30 June)

The Radio Corp. of America possessed rights to over 2,000 radio patents, including the most important ones of the period.

The Army discontinued its project for the remote control of torpedoes. The Navy continued the development. (30 July)

The First Annual Convention of the American Radio Relay League opened in Chicago, Ill. (30 Aug.)

In developing radio controlled aircraft (drones) the responsibility for the design, development, and tests of the radio equipment was assigned the Bureau of Engineering. (21 Oct.)

Comdr. S. C. Hooper, USN, advised the Radio Corp. of America of the Government's dissatisfaction with its policies.

A consortium of American, British, French, and German companies was formed, with U.S. Government approval, to operate circuits between the United States and South American countries.

Young's plan for the cooperation of the Federal Telegraph Co. and the Radio Corp. of America for the provision of radio facilities in China was approved by Secretary of the Navy, Edwin C. Denby, provided the approval of both the Chinese and the U.S. Governments were obtained and that in establishing the circuit with China no tacit approval of a monopoly would be considered to exist.

Young stated he agreed with the first proviso of Denby's letter but that it was impracticable, that he did not understand why the Navy entered the discussion, and ended by stating that he considered a monopoly in radio by the Radio Corp. of America was esential in the interest of American nationals.

The Radio Corp., by this date, operated the U.S. terminals of circuit with England, Japan, Germany, Norway, Austria, France, Poland, and countries of the South American consortium. (31 Dec.)

Twenty-seven amateur radio stations in the United States, transmitting on high frequencies, with power outputs varying between 50 and 1,000 watts were received in Scotland.

Several House resolutions were introduced for the purpose of appropriating funds to carry out the recommendations of the Interdepartmental Radio Board for the payment of infringement damages. Neither of these resolutions was adopted, Congress considering that these matters should be processed through the U.S. Court of Claims.

The Government returned the radio patents purchased from the Federal Telegraph Co. in 1918 but retained a nonexclusive, nontransferable, nonrevokable license to use these and future patents granted the Federal Telegraph Co. or its successors.

The United Fruit Co. became a corporate partner in the Radio Corp. of America.

The Radio Corp. of America refused to enter into a radio patent cross-license agreement with the Navy.

1922

The Bureau of Engineering assigned a project to the Naval Aircraft Radio Laboratory for the design and development of radio equipment for the remote control of aircraft. Mr. C. B. Mirick was designated project engineer. (28 Jan.)

The U.S. Senate ratified the treaties stemming from the Washington Conference on the Limitation of Armaments. This resulted in a sharp reduction in the funds available for research in and procurement of electronic equipments.

A timing device developed under the direction of Dr. H. C. Hayes, Naval Experimental Station, for measuring deep depths by sonic means was tested in the U.S.S. *Ohio* and found to be extremely accurate.

The First National Radio Conference convened in Washington, D.C. (27 Feb.)

A new U.S. naval policy was promulgated which required the maintenance and operation of a communication system based upon a two-ocean war and the development of all forms of fleet communications required for battle efficiency. (29 Mar.)

Radio communications during the winter exercises of 1921–22 were entirely unsatisfactory, and the commanders of both the Atlantic and Pacific Fleets reported a requirement for immediate improvement. Among numerous other difficulties, the Model TC transmitter proved unreliable and unsatisfactory and the use of the force tune system created so much interference that it was impossible to receive messages. Following this, the contract for the Model TG transmitter, which had not been placed in production, was cancelled, and the Bureau of Engineering stated it would make no further procurement of vacuum tube transmitters until such time as improved models became available.

Congress authorized continued use of Naval radio stations for commercial traffic and press, on a noncompetitive basis, until 30 June 1925. (14 Apr.)

Eighty radio broadcasting stations possessed Department of Commerce licenses. It was estimated that there were between 500,000 and 700,000 radio receivers in the United States. Interference between broadcasting stations and naval radio stations was increasing daily and the Navy was subjected to much criticism by the public for disrupting broadcast reception. (1 May)

The Naval Aircraft Radio Laboratory broadcasted President Warren G. Harding's address dedicating the Lincoln Memorial, Washington, D.C.

A new underwater sound system (sonar) utilizing a Fessenden oscillator and MV hydrophones, combined with the accurate timing system developed by H. C. Hayes, was tested in the U.S.S. *Stewart* en route from Newport, R.I., to Chefoo, China, via the Suez Canal. A continuous profile of the ocean's floor was made along the ship's track for the entire voyage.

Owen D Young acknowledged that Comdr. S. C. Hooper, USN, was the motivating force in the establishment of the Radio Corp. of America.

Major E. H. Armstrong announced his superregenerative receiving circuit. (28 June)

The U.S.S. *Ohio* was decommissioned. This necessitated the use of operational ships for service testing radio equipment and materially slowed performance of these functions.

A new organization, which established the U.S. Fleet under a commander in chief, was placed into effect under the command of Adm. Hilliary P. Jones, USN. Lt. T. A. M. Craven, USN, became U.S. Fleet Radio Officer. (1 July)

A total of 198 broadcasting stations had been licensed. The "radio boom" in the United States was in full swing. This increased the requirement for vacuum tube transmitters and resulted in commercial companies increasing their research and development in that field. (1 July)

Thirty-one new broadcasting stations were licensed in the United States during the month of July.

The Radio Corp. agreed, under limited conditions, to provide three-element tubes to competing interests.

Personnel of the Naval Aircraft Radio Laboratory detected a moving object by means of reflected radio waves.

The Federal Telegraph Co. of of Delaware was formed by the Radio Corp. of America and the Federal Telegraph Co. of Calif. for the purpose of providing radio communications in China.

Vacuum tubes, with a General Electric Co. rating of 20 kw. were first used in a Radio Corp. of America transmitter at Rocky Point, N.Y. (5 Oct.)

Fleming's U.S. patent on the two-element tube expired. De Forest again began the manufacture of three-element tubes. (7 Nov.)

In 5 months the number of radio broadcasting stations in the United States doubled to a total of 569.

The Navy developed and installed an antenna system capable of transmitting several frequencies simultaneously.

Limited funds prevented further financial support to commercial manufacturers for the development of vacuum tube transmitters and this resulted in naval radio engineers designing vacuum tube transmitters which utilized as many components of the old spark transmitters as possible. The first of the alternating current tube transmitters was the Model TL designed for battleships. This was followed by the Model TM for submarines, the Model TN for shore stations and the Model TO for battleships.

1923

There were approximately 2 million radio receivers in use in the United States. It was estimated that over one hundred million dollars had been spent for radio equipment during the previous 24 months.

The Commander in Chief, U.S. Fleet, reported that rapid communications within the Fleet, between the Fleet and its bases, and between the Fleet and the Navy Department was neither satisfactory nor reliable. (14 Mar.)

The Second National Radio Conference was convened in Washington, D.C. Broadcasting interests, abetted by the public, demanded the Navy relinquish the 500–1500 kc. frequency band. The Interdepartmental Radio Advisory Committee agreed that, as soon as possible, the Navy would use the band only on a noninterference basis. (20 Mar.)

C. Francis Jenkins transmitted photographs by radio from Washington, D.C., to Philadelphia, Pa., with the assistance of naval radio personnel.

A radio control system for pilotless aircraft, designed and developed by Mr. C. B. Mirick of the Naval Aircraft Radio Laboratory, was successfully tested in a piloted F–5–L flying boat. (15 Apr.)

The Radio Corp. of America instituted suit against the A. H. Grebe Co., Inc., in an endeavor to maintain their monopoly of radio tubes. This action resulted in House Resolution 548 which directed the Federal Trade Commission to investigate and report upon the radio industry.

The Navy designed Model TL transmitter, utilizing spark transmitter components, was service tested and found to be satisfactory.

The U.S. Navy General Board concurred with the Commander in Chief, U.S. Fleet, concerning the unreliable and unsatisfactory state of naval communications.

Based upon the recommendations of the Commander in Chief, U.S. Fleet, and the concurrence in these by the General Board and in consonance with the newly promulgated naval policy, the Bureau of Engineering made plans for the modernization of naval radio equipment. Congress was requested to appropriate $2½ million for this purpose.

The Naval Research Laboratory was established at Anacostia, D.C. The Radio Division of this Laboratory consisted of the Naval Radio Research Laboratory, the Naval Aircraft Radio Laboratory, and the Naval Radio Test Shop of the Washington Navy Yard. Dr. A. Hoyt Taylor was the first head of the Radio Division. The Sound Division was formed under Dr. H. C. Hayes by transferring the sound personnel who had been working under his direction at the Naval Experimental Station, Annapolis, Md. (1 July)

The Chinese Government approved the provision of radio communication stations in China by the Federal Telegraph Co. of Delaware. (13 July)

The Mirick designed remote radio control system was installed in an N–9 plane equipped with the Norden automatic control system.

Capt. R. W. McNeely, USN, relieved Comdr. S. C. Hooper, USN, as Head of the Radio and Sound Division, Bureau of Engineering. Hooper was assigned duty as radio officer, staff Commander in Chief, U.S. Fleet. Craven became Head of the ship Section of the Radio Division. (July)

The final remote radio control flight testing for the year was made, with the plane in flight being controlled from the ground for 25 minutes. (14 Nov.)

The Naval Research Laboratory began exploration of use of frequencies above 2000 kcs.

The Naval Research Laboratory designed, constructed, and installed the first airborne high-frequency transmitter in the rigid airship U.S.S. *Shenandoah*.

All battleships were fitted with Model TL transmitters, and the CW 936 transceiver was modified and fitted to transmit interrupted continuous waves for use in intrafleet communications as a replacement of motor buzzer sets.

1924

The Commander in Chief's report of communications during the winter exercises pointed out that, although some improvement had been made in transmitters, unsatisfactory receiving equipment and lack of duplexing made Fleet radio communications entirely unsatisfactory. (19 Feb.)

A special board, appointed to investigate the deficiencies of radio communication within the Battle Fleet, reported that these were the result of a communication plan which was too complicated for the inadequate equipment and poorly trained personnel.

The Bureau of Engineering formulated a plan for the modernization and standardization of radio installations in capital ships. In accordance with the previous agreement to vacate the 500–1500 kcs. band, except on a noninterference basis, it envisioned the use of the 1500–4000 kcs. band for intrafleet communications.

The Commander in Chief, U.S. Fleet, commenting upon the Bureau of Engineering's modernization plan, stated that he could not concur in vacating the 500–1500 kcs. band until he could be assured that the 1500–4000 kcs. band would be satisfactory and that funds would be available to provide equipment utilizing that band. He further stated that, in his opinion, the number of commercial broadcast stations would be greatly reduced in the near future and that this would decrease the interferences in the broadcast band. (27 Mar.)

First transatlantic transmission of radio photo made by the Radio Corp. of America. (6 June)

Congress appropriated $1½ million for the modernization of naval communications.

Capt. Ridley McLean, USN, became Director of Naval Communications. (July)

Mr. M. P. Hanson, Naval Research Laboratory, designed the first high-frequency receiver, the Model RG, suitable for naval usage. The high-frequency transmitter built by the Laboratory the previous year and the RG receiver were used by the U.S.S. *Shenandoah* on her first round trip transcontinental flight. Almost continuous communications were maintained between the airship and the Laboratory during the flight.

The first sustained pilotless controlled flight of a plane was made using the Mirick remote radio control system and the Norden automatic pilot. The duration of this flight was 40 minutes, during which time it was put into the air, controlled through many maneuvers, and landed by a radio control station on the ground. (Prior to this both English and French personnel had managed to get a plane airborne and controlled for a few minutes.)

The Third National Radio Conference was convened in Washington, D.C. (6 Oct.)

The dirigible, U.S.S. *Los Angeles*, was delivered from Germany under its own power. It was equipped with German transmitters and receivers.

The Naval Research Laboratory in conjunction with amateurs, notably J. L. Reinartz and M. J. Lee, conducted studies of skip distances which resulted in the modification of existing wave propagation theories by Drs. A. H. Taylor and E. O. Hulbert of the Laboratory.

The Naval Research Laboratory reported that it was feasible to control a plane by radio beyond visual range. (22 Nov.)

Mr. L. A. Gebhard assisted by Messrs. Matthew Schenk and Edwin White, all of the Naval Research Laboratory, designed and constructed the first crystal-controlled high-frequency transmitter. They had the consultant services of Dr. Karl Van Dyke and Mr. Walter G. Cady, the country's two foremost authorities on quartz crystals.

1925

The Naval Research Laboratory completed the development of pulse radio transmitting equipment. This was done under the direction of Mr. L. A. Gebhard.

Congress extended the authority of naval radio stations to handle commercial and press traffic, on a noncompetitive basis, until 30 June 1927.

The greater portion of the $2½ million appropriated for the modernization of naval radio equipment during fiscal year 1925 lapsed because of lack of availability of equipment, lack of coordination between the Bureau of Engineering and the Bureau of Construction and Repair, the inability of the Bureau of Engineering and the Commander in Chief, U.S. Fleet, to agree upon a plan, and the lack of interest of most of the officers in the fleet.

U.S. Navy experimented in the use of high frequencies for communications on the U.S. Fleet cruise to Australia. The flagship, the U.S.S. *Seattle*, was able to maintain daily communications with the Navy Department, through the Naval Research Laboratory, during the major part of this cruise. Lt. Frederick Schnell, USNR and traffic manager of the American Radio Relay League, was called to active duty to conduct these tests in the U.S.S. *Seattle*. (June–Aug.)

The Naval Research Laboratory in cooperation with the Carnegie Institution confirmed the Kennelly-Heaviside Theory. The pulse transmitter developed by the Laboratory was utilized for this purpose.

Twenty-eight test flights of the Mirick remote radio control system and the Norden automatic pilot installed in a Vought plane were conducted between 19 June and this date. None were completely successful. (14 Sept.)

Following successful experiments utilizing high frequencies for long-distance communications, the Commander in Chief, U.S. Fleet, recommended the modification of the fleet frequency plan to utilize these frequencies. He further recommended that ship-shore circuits not use frequencies above 9000 kc. (Sept.)

A successful remote control flight was made using the Mirick remote radio control system and the Norden automatic pilot installed in a Vought plane. A safety pilot was in the plane. (28 Oct.)

An unsuccessful attempt was made to fly a Vought plane by remote radio control. Following this failure interest waned in the project and it remained almost dormant until 1936.

Lt. T. A. M. Craven, USN, assisted by officers of the Naval Communications Division developed a U.S. Navy radio frequency plan which utilized frequencies up to 20 mc. and used the broadcast band only on a noninterference basis.

1926

The Interdepartmental Radio Advisory Committee approved a U.S. Naval Communications Frequency Plan which utilized frequencies from 15 kc. to 19 mc. (25 Feb.)

S. C. Hooper became Head of the Radio Division of the Bureau of Engineering for the third time.

The Chief of the Bureau of Engineering released information concerning a revised radio modernization plan. (8 Mar.)

The Attorney General of the United States was forced, by court decision, to issue the edict that the Secretary of Commerce did not have the power to withhold radio transmitting licenses from reputable citizens. (16 Apr.)

The Radio Corp. of America established point-to-point radio facsimile service between New York and London and transmitted first commercial picture across the Atlantic. (1 May)

The performance of the Naval Research Laboratory XA high-frequency radio transmitter proved most satisfactory. (20 July)

Radio receivers powered by 110-volt alternating current were introduced for home use.

The Radio Division of Naval Research Laboratory was directed to cease operation and manufacture of radio equipment and to expend all its efforts on research and development. (27 Oct.)

The Radio Corp. of America, the General Electric Co., and the Westinghouse Electric & Manufacturing Co. were requested to cooperate with the Naval Research Laboratory in research, development and design of new naval radio equipments. These companies took the position that such cooperation would endanger their own developments. (11 Nov.)

An 80-kw. vacuum tube transmitter was installed at the Naval Radio Station, San Diego (Chollas Heights), Calif.

Lt. Comdr. (later Rear Adm.) Richard Evelyn Byrd, USN (retired) flew over the North Pole. His aircraft was fitted with a high-frequency transmitter.

1927

Mr. P. T. Farnsworth filed a patent application covering an electronic television system. (7 Jan.)

The Radio Act of 1927 was enacted by Congress. This gave the Secretary of the Navy authority, under certain stipulations, to utilize all naval radio stations for the transmission and reception of commercial messages. Additionally, it authorized him to prescribe and collect reasonable tariffs for the handling of such messages.

President Coolidge approved the Radio Act of 1927, which established the Federal Radio Commission for a period of 1 year and vested in it the authority to license and control commercial and private radio transmitting stations. (23 Feb.)

The Federal Radio Commission was appointed. Rear Adm. W. H. G. Bullard, USN (retired), was the first chairman of the commission. (2 Mar.)

The Chief of Naval Operations approved a change in the modernization plan which eliminated installation of high-frequency radio equipments in numerous minor vessels. (31 Mar.)

The Bell Telephone Laboratories demonstrated landline television between Washington and New York and radio television between Whippany, N.J., and New York. (7 Apr.)

The Bell Telephone Laboratories demonstrated television, both image and sound, by means of a single radio transmitter using the same frequency band. (16 Apr.)

The Federal Radio Commission ordered 129 transmitting stations, which had been operating on unassigned frequencies, to return to those previously assigned them by the Department of Commerce.

Capt. T. T. Craven, USN, became Director of Naval Communications. (June)

The Commander in Chief, U.S. Fleet, requested more modern receivers powered by alternating current. (July)

The Fourth International Radio Conference was opened in Washington with a welcoming address by President Coolidge. Secretary of Commerce Hoover was the presiding officer of the conference. Capt. T. T. Craven, USN, was one of the U.S. delegates. Among other things, it established a permanent International Consulting Committee on Radio Communications to provide opinions and advice on technical questions of radio communications. (4 Oct.)

The first experimental sets of underwater supersonic echo ranging devices were installed in several naval vessels.

The Submarine Signal Co. began producing the Fathometer. This quickly became a standard installation for U.S. naval vessels.

1928

Congress reluctantly extended the authority of the Federal Radio Commission another year.

The National Broadcasting Co. received its first television station construction permit. (4 Apr.)

Rapid progress had been made in the modernization of fleet and shore radio equipment. (July)

Hooper became Director of Naval Communications and was relieved as Head of the Radio Division by E. C. Raquet. (July)

The reception of transmissions during the entire cross-country flight of an airplane was achieved by the Naval Research Laboratory.

The U.S. Government commenced installations of radio ranges as aircraft aids to navigation.

The U.S. Supreme Court reversed rulings of lower courts and awarded priority of invention of the "feedback" circuit to De Forest. (29 Oct.)

Dr. V. K. Zworykin of the Radio Corp. of America was granted U.S. Patent 1,691,324. This related principally to color television.

Commander (later Rear Adm.) Richard Evelyn Byrd, USN, (retired), headed an aerial exploration over the South Pole. The Naval Communication Service assisted him in this endeavor. One of the most notable accomplishments of the expedition was the transmission of more than 300,000 groups of press messages to the New York Times.

1929

The Convention and Regulations adopted by the Fourth International Radio Conference became effective. This included an allocation of frequency bands by usages based upon a plan adopted earlier by the U.S. Navy. (1 Jan.)

The Radio Corp. of America acquired control of the Victor Talking Machine Co.

Application for a patent on the Espenschied-Affel coaxial transmission cable was made. (23 May)

The Chief of Naval Operations approved a change to the 1926 radio modernization plan designed to meet the growing radio communications requirements of the fleet. (1 June)

The Naval Research Laboratory produced the JK electronic listening device which replaced the acoustic devices fitted in submarines.

The Naval Communication Service established area communication officers in the Atlantic, Pacific and Asiatic zones.

The Naval Communication Service conducted experiments to adapt the teletypewriter to radio.

Dr. A. W. Hull of the General Electric Co. announced the development of the screen-grid electronic tube.

Congress again extended the time limit and authority of the Federal Radio Commission.

Dr. V. K. Zworykin of the Radio Corp. of America demonstrated the kinescope (cathode ray television picture tube). (18 Nov.)

Rear Adm. R. E. Byrd, USN, (retired), flight over the South Pole was announced by radio from Little America, Antarctica.

1930

The London Naval Conference convened. (21 Jan.)

The Bell Telephone Laboratories demonstrated two-way landline television between stations 2 miles apart. (9 Apr.)

The "Annual Report of the Commander in Chief, U.S. Fleet," acknowledge the great improvement made in naval communications but continued to stress the need for more modern receivers. (1 July)

The Naval Research Laboratory designed and developed an RAC low-frequency barrage receiver for use at shore radio stations.

The Radio Corp. of America-Victor was awarded contract for design, development and manufacture of models RAA and RAB radio receivers.

Models TAU, TAZ, TBA, TBB, and TBC transmitters were purchased.

The JK listening device was modified by the addition of a small transmitter which produced "pings" which were utilized for underwater communications.

The Director, Naval Research Laboratory, submitted a detailed report on "Radio-Echo Signals from Moving Objects" to the Chief of the Bureau of Engineering. (5 Nov.)

The Bureau of Engineering directed the Naval Research Laboratory to investigate the use of radio to detect the presence of enemy vessels and aircraft.

Comdr. S. A. Monahan, USN, became Head of the Radio Division, Bureau of Engineering. (Dec.)

Direct commercial radio communications finally established between the United States and China.

Mr. P. T. Farnsworth advised the Federal Radio Commission that he had succeeded in narrowing the band required for television to 6000 kc.

1931

The Naval Research Laboratory developed the QB echo ranging sonar. This was fitted in newly constructed submarines in addition to the JK apparatus. This transducer utilized newly developed Rochelle salt crystals instead of quartz.

Models RAA and RAB superheterodyne, alternating current receivers installed afloat.

The U.S. Navy possessed the most modern and the most efficient radio system of any Navy.

Radio Section, Design Branch, Material Division, Bureau of Aeronautics, was established. (Aug.)

Mr. L. A. Hyland of the Naval Research Laboratory discovered that the echos of radio waves revealed the presence and location of aircraft in flight. (Sept.)

1932

Radio Section, Design Branch, Material Division, Bureau of Aeronautics, was retitled the Radio and Electrical Section. (Apr.)

The first of several high-powered vacuum tube transmitters was delivered the U.S. Navy and installed in the Naval Radio Station, Cavite, P.I.

A complete radio detection system for the air surveillance of an area about 30 miles in diameter was devised and enough components were installed to prove its capabilities. It was not satisfactory for shipboard usage and the Secretary of the Navy suggested it might meet the requirements of the Army.

The Fifth International Radio Conference convened in Madrid, Spain. The convention adopted by this conference was concerned with modifying the Washington Convention by providing additional channels for aviation communications and the further assignments of specific high-frequency long-distance communications channels.

1933

The Chief of Naval Operations was requested to provide forces afloat with high-speed, radio-controlled aerial targets. (22 Apr.)

The Director, Naval Research Laboratory advised the Bureau of Ordnance of the possibilities of controlling gunfire by microwave radio. (15 Sept.)

Comdr. W. J. Ruble, USN, became Head of the Radio Division, Bureau of Engineering. (Oct.)

The Washington Navy Yard had produced 20 sets of QB sonar. This was not sufficient and the Submarine Signal Co. was awarded a contract to provide 30 additional sets.

The Naval Research Laboratory in collaboration with the Goodrich Tire and Rubber Co. developed a spherical cover for the QB transducer which permitted submarines to make speeds up to 10 knots before water noises became excessive.

1934

Dr. V. K. Zworykin proposed the Navy develop an unmanned aerial torpedo. Naval officials concluded that it was unsuited as a naval weapon because of its weight, complexity and lack of penetration.

The Naval Research Laboratory designed, developed and constructed the world's first radar equipment.

Dr. R. M. Page was placed in charge of a special section of the Naval Research Laboratory to push radar and other high-frequency radio projects.

Dr. R. M. Page and his assistants at the Naval Research Laboratory designed and constructed their first radar equipment. During tests in December it proved unsatisfactory.

Mr. Leo Young suggested that pulse radio transmission might make it possible to colocate a radar transmitter and receiver. (Mar.)

The Communications Act of 1934 was signed by President Roosevelt. This established the Federal Communications Commission as the successor to the Federal Radio Commission. (9 June)

The Naval Research Laboratory developed a sonar transducer which utilized magnetostriction tubes instead of salt crystals. The Submarine Signal Co. began production of these at an annual rate of approximately 14. This company also adopted this transducer for use in the Fathometer.

Mr. W. F. Curtis of the Naval Research Laboratory experimented with magnetrons at about 750 mc.

Eitel-McCullough, Inc., developed a triode of greater efficiency. It was designated the 100 TH.

The U.S. Supreme Court upheld De Forest as the inventor of the "feedback" circuit. (9 Oct.)

Joint agreement between the Chiefs, Bureau of Engineering and Bureau of Aeronautics, provided that the latter would initiate all procurement requests for aircraft radio equipment and that the former would issue the requisitions and select the contractors subject to the latter's approval. (22 Oct.)

1935

The Naval Research Laboratory in collaboration with the Wood's Hole Oceanographic Institute instituted a study of oceanography and underwater sounds to determine the cause of the vagaries being encountered in the use of sonar.

The Radio Corp. announced that it would allocate $1 million for field television tests. (7 May)

Rear Adm. C. E. Courtney, USN, became Director of Naval Communications. (July)

Personnel of the Naval Research Laboratory under the direction of Dr. R. M. Page completed the design of the pulse radar transmitter circuit.

Mr. E. H. Armstrong demonstrated a frequency modulation system using a 2.5 meter wave. (6 Nov.)

1936

The Bell Telephone Laboratories developed coaxial transmission lines and waveguides.

The Chief of Naval Operations addressed a letter to the Bureaus of Ordnance, Aeronautics, and Engineering calling their attention to the urgent need of radio-controlled aerial targets. (23 Mar.)

The use of hollow tubing as a "waveguide" for the transmission of ultra-high-frequency radio waves was reported by Bell Laboratories and the Massachusetts Institute of Technology. (30 Apr.)

The Chief of Naval Operations directed the Bureaus of Aeronautics and Engineering to proceed with the development of four radio-controlled aircraft. (1 May)

Tests of the Naval Research Laboratory designed and constructed pulse radar equipment were successful. This used separate transmitting and receiving antennae. Mr. Leo Young of the Laboratory suggested the means of utilizing the same antenna for both purposes.

The Radio Corp. of America began tests to demonstrate the value of television in aerial reconnaissance.

The Bell System provided the first coaxial cable for television use between the studio and transmitter of the National Broadcasting Co. in New York. (10 June)

The Navy's pulse radar system was demonstrated to high Government officials. (10 June)

The Radio Corp. of America demonstrated ultra-short-wave radio facsimile between New York and Philadelphia using two automatic relay stations between the terminals. (10 June)

The Radio Corp. of America demonstrated the operation of a complete two-way radio relay system, using frequencies above 30 mc. between New York and Philadelphia. (11 June)

The Chief of the Bureau of Engineering directed that the Navy's radar project be given the highest possible priority. (12 June)

The duplexer, permitting use of a single radar antenna, designed and developed by the Naval Research Laboratory, was completed.

The Naval Research Laboratory commenced design and development of two sets of radar equipment for shipboard installation. One was a 200 mc. pulse type, the other a 1,200 mc. phase shift type, modulated at 30 kc.

The Bureau of Aeronautics established a radio-controlled aircraft project under the direction of Lt. Comdr. D. S. Fahrney, USN. (20 July)

Personnel of the Naval Research Laboratory used the magnetron to produce oscillations at 3,000 mc. but did not achieve reliability.

The Fleet Sonar School was established at San Diego, Calif. to train sonar operators in its use and in the science of oceanography.

The American Telephone & Telegraph Co. coaxial cable between Philadelphia and New York was placed under test. (1 Dec.)

The Secretary of the Navy approved a joint agreement between the Chiefs of the Bureaus of Engineering and Aeronautics wherein the former was made responsible for research, design, development, and procurement of aircraft radio equipment subject to the approval of the latter. The Bureau of Aeronautics was to define policies subject to the approval of the Chief of Naval Operations and was to provide specific items which it desired research and development pushed. Direct charges of these programs were to be financed by the Bureau of Aeronautics. (31 Dec.)

1937

The Naval Research Laboratory made complete disclosure of its radar development to the Army Signal Corps Laboratory. (18 Jan.)

The Philco Radio & Television Corp. demonstrated television of 44 lines in a 3-mile test in Philadelphia. (11 Feb.)

Personnel of the Naval Research Laboratory completed the development and satisfactorily operated the control system of a drone at a distance of 25 miles. The design and development of the control equipment was carried out under the direction of Mr. Matthew Schrenk. (17 Feb.)

A board of officers' convened to examine a proposal of Dr. V. K. Zworykin to develop guided missiles' reported unfavorably on the project. (27 Feb.)

A Navy drone, with safety pilot, was controlled in flight by radio. (29 Mar.)

The Assistant Secretary of the Navy and the Chief of Naval Operations witnessed a demonstration of Navy developed radar equipment.

Two radar sets were installed in the U.S.S. *Leary* for testing. The pulse-type equipment located planes at ranges of 18 miles.

Mr. V. K. Zworykin of the Radio Corp. of America demonstrated an electron projection "gun" which projected television pictures on an 8-inch by 10-inch screen. (12 May)

Capt. Leigh Noyes, USN, became Director of Naval Communications.

Complete disclosure of all technical details of radar were made by the Naval Research Laboratory to Bell Telephone Laboratory engineers and Western Electric Co. officials. The latter made a proposal to develop a 700-mc. equipment. (13 July)

Mr. T. A. M. Craven appointed a member of the Federal Communications Commission. (17 July)

The Army Signal Corps demonstrated a pulse-type radar based upon development work accomplished after they were provided information by the Naval Research Laboratory. (30 July)

The Federal Communications Commission authorized tests of radio facsimile on regular broadcast channels during early morning hours.

The Federal Communications Commission opened the spectrum to 30 mc. for various non-Government services and experimenters. (15 Oct.)

The Chief of the Bureau of Aeronautics directed an investigation be made concerning the use of radio control for flight-testing new aircraft.

A pilotless Navy drone was taken off the ground by a ground radio control station, maneuvered in the air by an airborne control station, and then landed by the ground control station. It was a hard landing which carried away a part of the landing gear. (15 Nov.)

A pilotless drone was put in the air, maneuvered, and landed without accident. (23 Dec.)

A conference of North American countries was held at Ottawa to ease the broadcast interferences between nations.

A conference of Western Hemisphere countries was convened in Lima, Peru, to discuss aeronautical radio problems.

A conference of Western Hemisphere countries convened in Havana, Cuba, to consider Western Hemisphere positions at the Sixth International Radio Conference.

1938

Two pulse radars, one directed ahead and the other down, were installed in a plane by RCA engineers as a safety-in-flight system.

The Federal Communications Commission allocated a band of 25 ultrahigh frequencies for non-commercial educational broadcasts. (27 Jan.)

The Sixth International Radio Conference convened in Cairo, Egypt. Capt. S. C. Hooper, USN, was one of the four U.S. delegates. As in the Madrid Conference, this one was primarily concerned with providing increased radio facilities for aviators, plus the allocation of the uses of the newly developed portion of the radio spectrum between 30 and 300 mc. (1 Feb.)

The Naval Research Laboratory was directed to complete a 200-mc. radar for shipboard installation and test prior to end of year. This was given the designation XAF. (24 Feb.)

The basic principles of radar were divulged to engineers of the Radio Corp. of America and that firm was given a contract to develop an experimental radar in the 400-mc. band. This equipment was for shipboard installation and test and was required to be ready for installation and test prior to the end of the year. This set was designated CXZ.

Lt. Comdr. J. H. Dow, USN, became Head of the Radio Division, Bureau of Engineering.

A 200-mc. radar equipment, utilizing a "multiple-tube ring-mounted transmitter oscillator" suggested by Dr. R. M. Page of the Naval Research Laboratory, was completed. It was successful in detecting aircraft for distances up to 48 miles.

The first operational radar installation on a U.S. Navy vessel was fitted in the U.S.S. *New York*.

Extensive training exercises were established for Naval Communications Reserve personnel. Over 2,700 private and Government stations were involved in these exercises.

A drone was first used by the Navy as an aerial target for the U.S.S. *Ranger*. Her antiaircraft batteries failed to make a hit on either of two runs.

A drone was used to simulate a dive-bombing attack on the U.S.S. *Utah*. It was brought down by a hit by the second salvo. (14 Sept.)

The Bell Telephone Laboratories demonstrated a radar altimeter. (10 Oct.)

1939

Mr. E. H. Armstrong demonstrated the use of frequency-modulated transmissions on 7.5 meters with a 40-kw. transmitter. (17 Jan.)

Tests of XAF and CXZ radar sets completed in the fleet. The XAF was considered very satisfactory but the CXZ proved of little value because of its hurried design and construction. (24 Mar.)

The Bell Telephone Laboratories designed, constructed and tested a 500-mc. radar. It was satisfactory for some applications but not for the control of gunfire.

Contracts were awarded the Submarine Signal Co. and the Radio Corp. of America for sonar equipments to equip all U.S. destroyers.

The radio equipment of the Navy, installed in the late 1920's and early 1930's was rapidly becoming obsolescent.

The Naval Radio Station, Cheltenham, Md., was commissioned as the radio-receiving center for the Navy Department and Potomac and Severn River naval activities.

The National Broadcasting Co. applied for a license for a frequency-modulated transmitting station. (13 July)

England and France declared war on Germany.

The Navy awarded first contracts for commercially manufactured radar equipments.

Tests with television equipment in aircraft were commenced by the Naval Aircraft Factory.

Contract awarded the Radio Corp. of America for the construction of six "Chinese copies" of the XAF radar equipment.

Rear Adm. Richard Evelyn Byrd, USN, (retired), led a second Antarctic exploration expedition. He was provided Navy communications personnel and equipment.

Personnel of the Naval Research Laboratory designed and developed a radio altimeter using a 500-mc. transmitter. It was placed under commercial production.

Dr. R. M. Page in a report to the Director, Naval Research Laboratory, stressed the need of a new tube to permit utilization of higher frequencies for radar in order to reduce antenna size and weight.

During this year the Navy expended $1,500,000 for the purchase and maintenance of electronic equipments.

In the Navy there were approximately 122,000 personnel. Of this number, about 1,500 officers and 10,500 men were engaged in communications.

1940

There were 743 licensed radio stations broadcasting to 45,300,000 receivers. Nine experimental frequency-modulated stations were licensed at this time. (1 Jan.)

Radio Corp. of America engineers designed a compact transmitter and camera to provide airborne television.

A Naval Research Laboratory report reiterated the requirement for developing a new tube in order utilize higher frequencies in radar equipments and stated the importance of integrating identification and recognition systems with radar. It also emphasized the necessity of applying radar to fire control and the development of repeater units and the plan position indicator. (26 Feb.)

The Federal Communications Commission approved limited commercial television operations effective 1 September 1940.

The Chief of the Bureau of Aeronautics directed that a radio-controlled plane be fitted to fly at a set altitude, just clear of the water to determine the practicability of the use of radio-controlled torpedoes. The tests indicated that it could be flown into a target consistently by a control operator flying 1½ miles astern of it.

A decision of the Supreme Court made it possible for the Federal Communications Commission to license new broadcast stations without regard to possible economic injury to existent stations.

The Western Electric Co. was awarded a developmental contract for one fire-control radar, designated CXAS.

President Roosevelt directed that every effort be exerted to prevent a monopoly of television.

The Naval Research Laboratory requested that funds for radar research for fiscal year 1941 be more than doubled.

The Radio Corp delivered six radar equipments, designated CXAM, to the Navy.

The Federal Communications Commission unanimously rescinded its 28 February order that limited commercial television operations would begin on 1 September 1940.

The Chief of Naval Operations directed immediate expedition of radar research. (1 June)

Public Law 671 was enacted. This eliminated archaic methods of material procurement.

Italy entered the war as an Axis partner.

France capitulated to Germany. (17 June)

The National Defense Research Committee was established. (27 June)

The Bureau of Engineering and the Bureau of Construction and Repair were consolidated into a single Bureau of Ships. Concurrent with a departmental reorganization, the Radio and Sound Division became the Radio and Sound Branch, Design Division, Bureau of Ships. (1 July)

Comdr. A. J. Spriggs, USN, became Head of the Radio and Sound Branch, Bureau of Ships.

The Federal Communications Commission announced that it had authorized 22 experimental frequency-modulated transmitter stations.

A Microwave Research Committee was established under the National Defense Research Committee.

The Navy negotiated a contract with the Radio Corp. of America for 14 CXAM–1 radar equipments.

The Chief of the Bureau of Ships stated that the Navy would require $10 million for radar, research, development and procurement in 1941 and twice that amount in 1942.

The Western Electric Co. was awarded a contract for surface fire-control radar equipment operating at 500 mc. (25 July)

The Bureau of Ordnance made an informal request to the National Defense Research Committee for the development of a proximity fuze. (12 Aug.)

The National Defense Research Committee established a section under Dr. M. A. Tuve to conduct research looking to the development of a proximity fuze. (17 Aug.)

Commercially constructed radar equipments were installed in some Navy vessels.

The British Technical Mission arrived in Washington for the purpose of exchanging research information with the National Defense Research Committee.

The U.S. Government was advised of the British improvement to the magnetron which made it capable of supplying oscillator power in the microwave band.

The Defense Communications Board was created to plan for the use of communications in the National defense. Its original members were James L. Fly of the Federal Communications Commission; Rear Adm. Lee Noyes, USN; Maj. Gen. J. O. Mangborne, USA; H. E. Gaston, Treasury Department; and Breckinridge Long, State Department.

The first multicavity resonator magnetron constructed in this country was completed at the Bell Telephone Laboratories. (10 Oct.)

The British Technical Mission suggested that the United States undertake the development of a microwave aircraft interception system and a microwave antiaircraft fire control system.

Upon resumption of military scientific exchange with England, it was discovered that underwater sound developments in the two countries had been almost parallel. England had continued the use of quartz-steel transducers in their Asdic but had developed a streamlined dome which further reduced water noises. The Asdic was capable of permanent recording ranges. The United States adopted both of these improvements.

The Chief of the Bureau of Aeronautics advised the Chief of Naval Operations that a number of projects were under examination, some of which would lead to the development of a guided missile.

The Federal Communications Commission issued the first construction permits for frequency-modulated broadcast stations. (31 Oct.)

The Radiation Laboratory, under the administration of the Massachusetts Institute of Technology, was established by the Microwave Committee and commenced operations.

Mr. Alfred L. Loomis made the initial suggestion for an electronic air navigation system which was later developed into Loran (long range navigation system) by the Radiation Laboratory of the Massachusetts Institute of Technology.

The use of the term "radar" was directed by the Chief of Naval Operations in nonclassified reference to "radio detection and ranging." (18 Nov.)

The Western Electric Co. was awarded a contract for 10 CXAS–1 (later designated FA) fire-control radars. (2 Dec.)

The Navy purchased a quantity of British 175-mc. airborne search radars. These were modified by the addition of a duplexing system and the elimination of one antenna.

The Naval Research Laboratory designed and developed the XAR 200-mc. search radar. Contracts were awarded the General Electric Co. and the Radio Corp. of America for engineering and producing equipments based upon the Laboratory models. These were designated the SC and SA, respectively.

The Naval Research Laboratory designed and developed an aircraft warning radar for submarines using the 114-mc. band. It was engineered and first produced by the Radio Corp. of America and was designated SD.

1941

There were 802 licensed radio broadcast stations transmitting to over 51 million receivers. (1 Jan.)

The Naval Research Laboratory commenced conversion of the radio pulse altimeter to an airborne search radar.

A 10,000-mc. multicavity resonator magnetron was completed and tested by the Bell Telephone Laboratories. It did not produce satisfactory peak-pulse power. (18 Jan.)

The Radio Corp. of America completed the development of a radar altimeter which gave excellent low-altitude performance. (27 Jan.)

U.S. Navy directed concentration on the development of an electronic proximity fuze.

A 700-mc. multicavity resonator magnetron was completed and tested at the Bell Telephone Laboratories. (14 Feb.)

Tests of Radio Corp. of America television equipment provided usable picture informations from a plane in flight to a ground receiver station up to a distance of 30 miles. (17 Feb.)

Dr. R. M. Page of the Naval Research Laboratory designed and developed the plan position indicator.

In consonance with the agreement reached at the Regional Radio Conference at Havana, Cuba, the frequency assignments of 777 United States broadcasting stations were reallocated.

The National Defense Research Council established a division under Dr. J. F. Tate to conduct research in underwater sound and oceanography. Numerous contracts were awarded scientific groups and universities to assist in this program.

The Chief of the Bureau of Ordnance suggested that all-out efforts should be made to develop the guided missile. (15 Apr.)

The Chief of the Bureau of Aeronautics advised that progress in the guided missile program was satisfactory and that radar was being developed as a guidance system. (18 Apr.)

Lt. Comdr. G. G. B. Hall, USN, became Head of the Radio and Electrical Section, Design Branch, Material Division, Bureau of Aeronautics. (24 Apr.)

The Aircraft Radio Maintenance Section, Maintenance Division, Bureau of Aeronautics, was established. (1 May)

An improved 700-mc. multicavity resonator magnetron was completed, tested at the Bell Telephone Laboratories, and placed under production by the Western Electric Co.

A "breadboard" model of the (SG) microwave surface-search radar, equipped with the Naval Research Laboratory plan position indicator, was tested on the U.S.S. *Semmes*. It produced excellent results.

Tests of airborne television equipment provided pictures of sufficient quality on the receiver in another plane to permit the pilot of the latter to direct the pilot of the former to pass directly over a preselected target.

The Radio Corp. of America developed a small television system which weighed only 70 pounds and proved successful in providing telemetering information.

The SG microwave surface-search radar was placed under production contract.

A "breadboard" model of the FC surface fire-control radar was completed and tested. Its performance was far superior to the model FA and it was placed under limited production.

An improved 10,000-mc. multicavity resonator magnetron was completed and tested by the Bell Telephone Laboratories. Plans were made to place this under contract but the strapped magnetron was developed prior to production. (11 June)

The Bureau of Aeronautics abandoned its previous policy of installing electronic equipment in planes and established the policy of having aircraft contractors install nonclassified equipments.

Commercial operation of television began in the United States with 21 licensed transmitting stations.

The Naval Research Laboratory commenced the development of a drone radar and radar repeat-back system. The National Defense Research Council commenced the development of a drone 3-cm. radar recognition system. (1 Aug.)

Forty-seven of fifty simulated torpedo attacks with the guided missile carried out during the month were successful.

The first model FD aerial radar fire-control system was completed and tested satisfactorily. It was later installed in the U.S.S. *Roe*. (28 Aug.)

The Bell Telephone Laboratories developed "lobing."

Numerous commercial companies participated in research and development of the proximity fuze.

The Naval Research Laboratory provided the Westinghouse Electric & Manufacturing Co. and the Radio Corp. of America information on which to construct preproduction models of the airborne search radar conversion from the radio pulse altimeter. It was designated ASB.

British scientists at Birmingham University developed the strapped magnetron. The Bell Telephone Laboratories produced a similar one within a week after receiving information concerning this tube.

Destroyers, totalling 170, were the only United States naval vessels equipped with sonar.

Delivery of production models of the FD radar commenced.

Japan attacked Pearl Harbor, Hawaii, at 1300 e.s.t. (7 Dec.)

All United States amateur radio stations closed by order of the Federal Communications Commission.

The U.S. Government declared war on Japan, Germany and Italy.

Comdr. J. B. Dow, USN, became the Head of the Radio and Sound Branch, Design Division, Bureau of Ships.

The Navy established its first landline teletypewriter system linking naval activities at Washington, Norfolk, Philadelphia, New York, New London, Boston, and Portsmouth, N.H.

President Roosevelt established a Director of Censorship for radio and press. The U.S. Weather Bureau placed a ban on all weather broadcasts.

President Roosevelt granted the military departments authority to negotiate contracts. (27 Dec.)

Mr. Loren F. Jones completed the development of *teleran* (television radar air navigation system).

1942

By the beginning of this year an airborne microwave radar set (ASV) for the detection of surface vessels had been developed and placed under production.

The Office of Procurement and Material was established within the Navy Department. This office was authorized to act for the War Production Board.

Material procurement was handicapped by lack of allowances, archaic methods of procurement, lack of price experience, and insufficient production capabilities.

The Production Division, Bureau of Aeronautics, took over the responsibility for financing and procuring aircraft radio equipments.

Quantity production of good, high-power 3,000- and 10,00-mc. strapped magnetrons was commenced by the Western Electric and other manufacturing companies.

Office of Facts and Figures (Office of War Information) designated as clearinghouse for U.S. Government radio broadcasts. (16 Jan.)

Trials of the proximity fuze proved successful.

War Production Board advised the electronic industry that it must be converted totally to war production within 4 months. (13 Feb.)

A thorough study of the physical and electrical characteristics of each ship type was commenced.

The responsibility for research and development of the proximity fuze was transferred to the Director of the Office of Scientific Research and Development and was placed under the administration of Johns Hopkins University's Applied Physics Laboratory.

War Production Board ordered radio manufacturers to discontinue making radios and phonographs for civilian use by 23 April. (7 Mar.)

The Chief of Naval Operations directed tests be conducted to determine the necessary characteristics for assault drones and their control planes and the tactical employment of assault drones.

The Bureau of Aeronautics was directed to procure 200 expendable assault drones. (23 Mar.)

Further tests of the proximity fuze indicated that the design was satisfactory.

War Production Board ordered electronic tube manufacturers to discontinue the production of 349 types of tubes by 24 April to save critical materials and manpower. (17 Apr.)

The Naval Electronics Laboratory was established at San Diego, Calif.

Delivery of airborne search radars (ASB) was commenced.

An electronics procurement section was established in the Radio Branch, Design Division, Bureau of Ships. All procurements were thereafter made by that section.

The Naval Aircraft Factory was directed to make a study of controlling assault drones from surface vessels and submarines by means of radio and 3- or 10-cm. radar.

The Vice Chief of Naval Operations established Project Option, appointed Capt. Oscar Smith, USN, as his direct representative for this assault drone program, and directed that the number of drones to be procured be increased from 200 to 1,000.

The Chief of the Bureau of Aeronautics requested that Project Option be cut by 50 per cent because of the enormous effect the original plan had upon training and upon the overloaded aircraft industry. (29 June)

All domestic radiotelegraph operations were discontinued by U.S. Government order.

The Army-Navy Communications Production Expediting Agency was established.

A Progress Section, Production and Procurement Branch, Bureau of Ships, was established to bolster the Navy's electronic production program.

The Seventh International Radio Conference which had been scheduled to be held in Rome was not convened at that time. It was finally held at Atlantic City, N.J., following the termination of hostilities.

The Chief of Naval Operations approved cutting back Project Option by 50 percent. (12 Aug.)

The U.S.S. *Cleveland*, testing the proximity fuze under simulated battle conditions, destroyed all the three provided drones with four proximity bursts. (12 Aug.)

The Radio Corp. of America developed a radar "sniffer" for aircraft or drone which could detect a target ahead and cause a torpedo to be launched or a bomb to be dropped at a preselected distance from the target. At the suggestion of Lt. M. B. Taylor, USN, right and left switching was added to make this device "target seeking."

Mass production of proximity fuzes commenced. Initial cost per fuze was $732. Procurement contracts were let in the amount of $60 million.

The "maintenance of true bearing" instrument, the "bearing deviation indicator' and the "reverberation gain control" instrument were developed to increase the efficiency of sonar equipments.

The first Loran System (long range navigation system) was placed in operation with four stations between the Chesapeake Capes and Nova Scotia.

The expanding scope of electronics necessitated the reestablishment of the Radio and Sound Division, Bureau of Ships.

The U.S. Government (Office of War Information) took over the operations of short-wave broadcasting stations. (1 Nov.)

The Army-Navy Communications Production Expediting Agency was reorganized and retitled the Army-Navy Electronics Production Agency (ANEPA).

The effectiveness of sonar was demonstrated when 1,065 assorted Allied vessels made passages from United States and United Kingdom ports to North Africa with the loss of only 23 ships despite a vigorous submarine offensive.

Electronics played an important part in the Allied invasion of North Africa.

Sonar production facilities of the Submarine Signal Co. and the Radio Corp. of America were greatly expanded. Additional companies established facilities and began producing sonar equipment. The Navy began fitting lightweight sonars in torpedo patrol boats, submarine chasers, motorboats and yachts. Bathythermographs were provided vessels for the purpose of locating thermoclines and increasing the efficiency of the use of sonar.

The Bureau of Ships abandoned a policy of earmarking electronics equipments for a particular activity and established pools of electronics equipment at navy yards and overseas bases.

Twelve assault drones delivered and underwent Board of Inspection and Survey trials.

The Secretary of the Navy approved a clarification of the joint agreement between the Chiefs of the Bureaus of Engineering and Aeronautics which stated that the Bureau of Aeronautics controlled and prepared descriptive performance specifications of aircraft electronics equipments. (4 Dec.)

Comdr. Frank Akers, USN, became Head of the Radio and Electrical Section, Design Branch, Material Division, Bureau of Aeronautics.

The Secretary of the Navy directed the material bureaus to handle their own contracts for research, development and procurement of technical items under each Bureau's cognizance. Procurement of standard items of a nontechnical nature remained the responsibility of the Bureau of Supplies and Accounts. (13 Dec.)

1943

The U.S.S. *Helena* fired the first proximity fuzes used in combat. (5 Jan.)

It was recommended that the "airborne remote control bomb" (assault drone) be brought into early action by trained crews and in sufficient numbers to benefit from its surprise use. (8 Mar.)

The Chief of Naval Operations directed that plans and training for use of the assault drone proceed immediately and rapidly. On this date Project Option was increased to 3,000 drones with a delivery rate of 250 per month to be achieved by June 1944. (23 Mar.)

The Naval Aircraft Factory was directed to manufacture 100 plywood assault drones and to contract for another hundred to be delivered prior to November 1943. (30 Mar.)

The Radio Corp. of America completed development of the "supersniffer" which had all the capabilities of the "sniffer" and the added one of being able to search an arc ahead and lock upon a discovered target. The specifications for this device required a range of 2 miles.

At the request of the Chief of the Bureau of Aeronautics, Project Option was cut back to 2,000 assault drones. (12 Apr.)

The "Chain Broadcasting Regulations" issued by the Federal Communications Commission became effective following a Supreme Court decision upholding their validity.

Sonobuoys, which could be dropped from planes, and high-frequency direction finder stations were used to guide planes and hunter-killer groups to German submarine wolf packs.

The Radio and Electrical Branch, Engineering Division, Bureau of Aeronautics, was established.

Procurement contracts for proximity fuzes totalled $200 million.

The Commander in Chief, Pacific Fleet, recommended against the use of the assault drones in his theater of action. This was based upon the lack of available carriers, the low speed and poor maneuverability of the drones and because conventional weapons were winning the war in that area. (22 Sept.)

1944

Captain H. B. Temple, USN, became head of the guided missile program in the Office of Chief of Naval Operations. Following a study of the program, he recommended that it be cut back and changed to a "combat test" program. (15 Feb.)

The number of assault drones was reduced to a total of 388. No reduction was made in the procurement of electronic equipment since it was planned to use this in obsolete aircraft. (5 Mar.)

Germany began V-bomb attack on England.

The Army-Navy Electronics Production Agency (ANEPA) was disestablished despite Navy opposition. This left the Navy with inadequate field expediting services.

The Radio and Sound Division was reorganized and established as the Electronics Division, Bureau of Ships.

Bureau of Ships electronic procurement was transferred to a Contract Division. A Contract Planning Section was established in the Equipment Branch of the Electronics Division to provide technical assistance to the Contract Division.

Approved contractors began fitting newly constructed aircraft with complete electronics installations.

There were more than 22,000 officers and 225,000 enlisted personnel engaged in U.S. Naval Communications.

Radio photo (facsimile) equipments were installed at Naval Communications stations at Washington, San Francisco, Pearl Harbor, and Guam.

Successful tests of radioteletypewriter equipments were conducted on several fleet radio circuits.

Major fleet radio circuits were equipped with radioteletypewriter equipments.

The proximity fuze was instrumental in defeating the German *V-1* attacks on London and Antwerp.

A military armistice was signed between the Allies and Italy. (8 Sept.)

The Allies gained the initiative in the Battle of the Atlantic.

The German Navy developed and equipped their submarines with snorkels, remained submerged for long periods, ceased using high-frequency radio, and reduced the effectiveness of our antisubmarine measures.

Proximity fuzes were used against enemy infantry at the Battle of the Bulge and were instrumental in changing the tide of victory. Procurement contracts for the fuze amounted to $300 million for the year 1944.

The Bureau of Ordnance relieved the Office of Scientific Research Development of all responsibility for the proximity fuze program. The Applied Physics Laboratory continued to administer the program.

Allies maintained the initiative in the Battle of the Atlantic, sinking 88 submarines and about 100 midgets while losing only 56 ships.

1945

Nine hundred and forty-three broadcasting stations held licenses in the United States. Seven hundred and thirty of those stations were affiliated with broadcast networks. (1 Jan.)

Nine commercial television stations were in operation. 112 applications for operation of television stations were on file with the Federal Communications Commission.

T. A. M. Craven was succeeded by Charles R. Denny as a member of the Federal Communications Commission. (14 Mar.)

Germany unconditionally surrendered to the Allies. (7 May)

The Federal Communications Commission reported 46 commercial frequency-modulated stations were in regular operation and that they had 403 applications for new frequency-modulated stations on file. (30 May)

The Federal Communications Commission announced frequency allocations from 10 kc. to 30 mc. for nongovernmental services. These allocations included bands for frequency-modulated transmissions and for television. (27 June)

The world's first atomic bomb used in offensive operations was dropped on Hiroshima, Japan. (6 Aug.)

An atomic bomb was dropped on Nagasaki, Japan.

Japan accepted allied surrender terms. (14 Aug.)

The War Production Board removed the wartime controls on the manufacture of radio equipment for civilian usage. (20 Aug.)

The Federal Communications Commission lifted the wartime ban on one amateur radio band.

The Office of War Information was abolished by Executive order. (31 Aug.)

Between 1 November 1942 and this date, contracts had been awarded for electronic equipment in the value of $4,009 million. During the same period, deliveries had been made in the amount of $2,538,000. (1 Sept.)

Formal singing of the surrender document on board the U.S.S. *Missouri* was transmitted from that ship to the naval radio station, Mare Island, Calif., by radio photo. (1 Sept.)

The Radio Technical Planning Board was organized to advise government, industry, and the public of the engineering considerations involved in the future utilization of electronics. (15 Sept.)

The War Production Board announced that $7,680 million was the approximate value of electronic equipment delivered for war purposes between July 1940 and July 1945. More than 550,000 workers in over 1,600 factories contributed to that effort. (5 Oct.)

The Federal Communications Commission lifted the wartime ban on all amateur radio bands.

Procurement contracts for the proximity fuze totalled $450 million for the year. Its cost had dropped from $732 each (1942) to $18 each (1945).

Appendix B. Final Protocol, First International Radio Telegraphic Conference, Berlin, 1903

The delegations to the preliminary conference concerning wireless telegraphy designated below:

Germany, Austria, Spain, the United States of America, France, Hungary, Russia are unanimous in proposing to their Governments to examine the following general bases for an international convention:

Article I

Exchange of correspondence between ships at sea and coastwise wireless telegraph stations opened to general telegraphic service, is subject to the following rules:

Section 1. All stations whose field of action extends to the sea are called coastwise stations.

Section 2. Coastwise stations are required to receive and transmit telegrams originating on ships at sea without distinction as to the systems of wireless telegraphy employed by said ships.

Section 3. The contracting states make public the technical points of a nature to facilitate and accelerate communication between coastwise stations and ships at sea.

However, each of the contracting Governments can authorize stations situated in its territory, under such conditions as it may deem proper, to utilize several installations or special arrangements.

Section 4. The contracting states declare their intention to adopt, in order to establish the tariffs applicable to telegraphic service between ships at sea and the international telegraphic system, the following bases:

The total charge to collect for this service is established by the word. It comprises:

(a) The charge for transmission over the lines of the telegraphic system of which the amount is that fixed by the international telegraph regulation in force attached to the St. Petersburg Convention.

(b) The charge pertaining to the marine transmission.

The latter is, as the former, fixed by the number of words, this number of words being counted according to the international telegraphic rule as indicated in the paragraph above (a).

It comprises:

1. A charge called "charge of the coastwise station," which goes to said station;

2. A charge called "charge of the ship," which goes to the station installed on the ship.

The charge of the coastwise station is subject to the approval of the state on whose territory it is established, and that of the ship to the approval of the state whose flag the ship carries.

Each of the two charges should be fixed on the basis of equitable remuneration for the telegraphic work.

Article II

A regulation which will be attached to the proposed convention will establish rules for the exchange of communications between coastwise stations and those placed on board ship.

The prescriptions of this regulation may at any time be modified by common agreement by the administration of the contracting Governments.

Article III

The rules of the telegraphic convention of St. Petersburg are applicable to transmission by wireless telegraphy in so far as they are not contrary to those of the proposed convention.

Article IV

Wireless telegraph stations should, unless practically impossible, give priority to calls for help received from ships at sea.

Article V

The service of operating wireless telegraph stations should be organized, as far as possible, in a manner not to interfere with the service of other stations.

Article VI

Contracting Governments reserve to themselves, respectively, the right to make special arrangements between themselves, having for their object to oblige the companies operating wireless telegraph stations in their territories to observe, in all their other stations, the prescriptions of the proposed convention.

Article VII

The prescriptions of the proposed convention are not applicable to the wireless telegraph stations of the state not open to general telegraphic service, save in that which concerns the clauses which Articles IV and V are intended to cover.

Article VIII

Countries which have not joined the proposed convention will be admitted at their request.

Done at Berlin August 13, 1903.

Declaration of the Delegation of Great Britain

While engaged in itself to submit the above bases to the examination of its Government, the British delegation declares that in view of the situation in which wireless telegraphy finds itself in the United Kingdom this delegation ought to maintain a general reserve. This reserve relates especially to section 2 of the 1st article and to the application of the rules of Article V to the stations indicated in Article VII.

Done at Berlin August 13, 1903.

Declaration of the Italian Delegation

The delegation of Italy while agreeing to submit to the examination of its Government the propositions contained in the final protocol of the conference, ought, agreeably with the declarations made by its members in the several meetings, to make on account of the Government the following reservations:

Article 1st, Section 2.—It would accept the proposed text only on condition of the following addition being made: "Provided that all these systems give a known guarantee for good working in reciprocal correspondence with respect to the range, to the perfection of the organization, and to the surety of communications."

Article 1st, Section 3.—It cannot accept the first paragraph of this section because in the agreements concluded with M. Marconi the Government engages to keep the details of the installations secret.

Article VI.—It cannot accept the text of this article and it should limit itself to the declaration on the part of its Government it will endeavor to introduce in the agreements stipulated with M. Marconi some modifications in the desired direction.

Done at Berlin August 13, 1903.

Appendix C. The Conclusions, Recommendations, and Approval Inter-Departmental Board in Wireless Telegraphy [Roosevelt Board], 24 June 1904

Conclusions

The conclusions of the Board are:

That the science of wireless telegraphy has been advanced by the able and persistent work of the Signal Corps of the Army and the Weather Bureau of the Department of Agriculture, as well as by the experimental work of the Navy Department;

That wireless telegraphy is of paramount interest to the Government through the Navy Department, and that its use by the Signal Corps of the Army for communication between military posts of the Army and other necessary links will be necessary both in peace and war, and that such use shall be unrestricted. When interference seems probable between stations of the Navy and War Departments; the question involved shall be mutually settled by representatives of the two Departments;

That coastwise wireless telegraphy is not a necessity for the work of the Weather Bureau of the Department of Agriculture, provided that the necessary meteorological data for that Department can be collected by the stations of the Navy Department from ships at sea and by them sent to the Weather Bureau of the Department of Agriculture;

That the maintenance of a complete coastwise system of wireless telegraphy by the Navy Department is necessary for the efficient and economical management of the fleets of the United States in time of peace and their efficient maneuvering in time of war;

That the best results can be obtained from stations under the jurisdiction of one Department of the Government only, and that representatives of more than one Department should not be quartered at any station;

And finally the Board concludes that the Government must take the necessary steps to regulate the establishment of commercial wireless-telegraph stations among the states and between nations.

Recommendations

In order that the above conclusions may be carried into effect, the Board recommends—

That the Signal Corps of the Army be authorized under its chief to establish from time to time such wireless stations as he may deem necessary, and that they do not interfere with the coastwise wireless-telegraph system of the Government under control of the Navy Department; and further, that the Chief Signal Officer be requested to inform the Navy Department what stations of its system may be utilized to transmit messages for the Signal Corps or other bureaus of the War Department, and that representatives of the Signal Corps of the Army and the Bureau of Equipment of the Navy Department be at once requested to draw up such rules as will insure the efficient and harmonious carrying into effect of the above recommendations;

That the necessary steps be taken to have the Weather Bureau of the Department of Agriculture turn over to the Navy Department all coastwise wireless-telegraph apparatus now under its control, and such material as it may have in its possession which can be utilized by the Bureau of Equipment of the Navy Department, and that proper transfers of funds for this purpose be made;

That the Weather Bureau of the Department of Agriculture furnish to the Hydrographic Office of the Navy, and to the naval wireless-telegraph stations, or to other portions of the public service, such meteorological data as it or they may desire at no cost to them;

That the Department of Agriculture shall continue the work of its meteorological vessel reporting and storm-warning stations, as now constituted and provided for by law, and continue the control of seacoast telegraph systems, except wireless systems;

That the necessary steps be taken that the Navy Department may equip and install a complete coastwise wireless-telegraph system covering the entire coasts of the United States, its insular possessions, and the Canal Zone in Panama;

That the Navy Department be directed to receive from the Signal Corps of the Army, at such points as may be requested by the Chief Signal Officer of the Army, all messages for army posts within their radius, and transmit them, under such rules as may be agreed upon by the representatives of the Signal Corps and Bureau of Equipment, without cost to the Signal Corps of the Army;

That all meteorological reports from vessels of war or commerce or other sailing craft, now being forwarded direct to the Hydrographic Office of the Navy, shall be forwarded direct to the Weather Bureau, and the control of ocean meteorology be transferred to the Department of Agriculture, which already has ample law for doing this work;

That the estimates for the support of the Hydrographic Office of the Navy, or any other office of the Navy, for the next and succeeding fiscal years, do not contain any provision for the making of ocean forecasts, or for the publication of meteorological data, other than such as may be needed by the Hydrographer of the Navy for use on the pilot and other charts, which data shall be furnished by and credited to the Weater Bureau;

That it is the opinion of this Board that no meteorological work need or should be done by any portion of the Navy for the purpose of publication, or for the making of forecasts or storm warnings; that all such duties, being purely civil, should devolve upon the Weather Bureau of the Department of Agriculture in accordance with the organic act creating that Bureau;

That the wireless stations of the Navy Department shall, without charge to the Agricultural Department, receive and promptly transmit to the ocean or to islands, or to other places where the information can be made useful, the storm warnings of the Weather Bureau;

That the Navy Department shall request all vessels having the use of its wireless stations for the receipt of messages, to take daily meteorological observations of the weather when within communicating range and to transmit such observations to the Weather Bureau, through naval wireless stations, at least once daily, and transmit observations oftener when there is a marked change in the barometer; and that there shall be no charge against the Agricultural Department for these observations, or for the transmission thereof;

That representatives of the Department of Agriculture and the Bureau of Equipment of the Navy Department be directed to prepare the necessary rules for the harmonious and efficient carrying on of the above recommendations.

We recommend that as fast as the naval wireless telegraph stations are put in operation the Navy Department be directed to receive and transmit through these stations, free of charge all wireless messages to or from ships at sea, provided such stations do not come in competition with commercial stations, until such time as Congress may enact the necessary legislation governing this subject.

In asking for legislation on this point, the Board desires to invite attention to the fact that where wireless stations are needed for the merchant marine, as a rule the Navy will also require them. The Board believes it to be in the interest not only of governmental, but public economy and efficiency to permit the naval stations to handle the public service, for in the present state of the art but one station is desirable for the public interests in such places. As the needs of the Navy are paramount on account of the problem of national defense, private stations should not be allowed to locate to the disadvantage of the former. Moreover, there is at present no public need for multiplication of stations at these points.

It is admitted, however, that there may be special cases where private stations can serve a useful purpose and the Board believes that the Department of Commerce and Labor should have the duty of issuing licenses in such cases under such regulations as will prevent interference with stations necessary to the national defense. All private stations in the interior of the country should also be under supervision of the Department of Commerce and Labor.

This method placing private stations under full Government supervision is desirable in order to regulate them for their mutual and the public welfare, as well as from considerations of national defense. Aside from the necessity of providing rules for the practical operation of such stations, it seems desirable that there should be some wholesome supervision of them to prevent the exploitation of speculative schemes based on a public misconception of the art.

It is believed that invention and private enterprise should be encouraged in every legitimate way, and it is the policy of the Navy Department to do this. It has the means of assisting inventors that no other Department has, and it believes that in order for it to lead the navies of the world in this matter, which is of great importance to the national defense, that every reasonable facility should be given inventors, while at the same time it is working out the problems of the application of their inventions to its requirements in times of peace and war.

To prevent the control of wireless telegraphy by monopolies or trusts, the Board deems it essential that any legislation on this subject should place the supervision of it in the Department of Commerce and Labor.

Because international questions may arise, due to the fact that the use of wireless-telegraph stations in our own possessions may affect the use of similar stations in foreign countries, it is desirable for the Congress to enact legislation which will enable the Government properly to handle such cases; a failure to do so may seriously embarrass the Government at some future time.

It is thought that the legislation recommended in placing private stations under the supervision of the Department of Commerce and Labor will also cover this case.

In conclusion, the Board deems it essential that the Executive take such action as in his judgment seems wise to prevent the erection of private wireless-telegraph stations where they may interfere with the naval or military operations of the Government until legislation may be had by Congress on this subject.

Very respectfully,

R. D. EVANS, *Rear Admiral, USN*,
Representing the Department of Commerce and Labor.

H. N. MANNEY, *Rear-Admiral, USN*,
Representing the Navy Department.

A. W. GREELY, *Brigadier-General, USA*,
Representing the War Department.

WILLIS L. MOORE, *Professor*,
Representing the Department of Agriculture.

JOSEPH L. JAYNE, *Lieutenant-Commander, USN*,
Representing the Navy Department.

WHITE HOUSE,
Washington, July 29, 1904.

MY DEAR MR. SECRETARY: I am directed by the President to forward to you the accompanying report from the Inter-Departmental Board on Wireless Telegraphy, which he approves and directs that the several Departments concerned put its recommendations into effect. The Navy Department being that most in interest, this communication is made to it and it will please advise the other Departments of the action taken, sending them copies of the report.

Very truly yours,

WM. LOEB, JR.,
Secretary to the President.

Hon. PAUL MORTON,
Secretary of the Navy.

Appendix D. Proposed Legislation for National Control of Radio, 1905

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled.

SECTION 1. That a person or corporation shall not use or operate any apparatus for wireless telegraphy as a means of commercial intercourse among the several states or with foreign nations, nor upon any vessel of the United States engaged in interstate or foreign commerce, nor for the receipt or transmission of wireless telegraphic messages or signals the effect of which extends beyond the exclusive jurisdiction of the state or territory in which the same are made, or where interference would be caused thereby with the receipt of messages or signals from beyond the jurisdiction of the said state or territory, except under and in accordance with a license in that behalf granted by the Secretary of Commerce and Labor; but nothing in this act shall be construed to apply to the transmission and exchange of wireless telegraphic messages or signals between points situated in the same state, provided the effect thereof shall not extend beyond the jurisdiction of the said state or interfere with the reception of messages or signals from beyond said jurisdiction; and no license shall be required for the transmission or exchange of messages or signals by or on behalf of the Government of the United States. Any person or corporation who shall use and operate any apparatus for wireless telegraphy in violation of this section, or knowingly aid or abet another person or corporation in so doing, shall be deemed guilty of a misdemeanor and on conviction thereof shall be punished by a fine not exceeding five hundred dollars, and the apparatus or device so unlawfully used and operated may be adjudged forfeited to the United States.

SECTION 2. Every such license shall be in such form as the Secretary of Commerce and Labor shall determine and shall contain the terms, conditions and restrictions on and subject to which the license is granted, and shall be for a period of one year. Every such license shall specify the location of the station in which said apparatus shall be used and shall not be construed to authorize the use of any wireless telegraph apparatus in any other station than the one specified. Every such license shall be subject to such regulations as may be established sequent Acts and treaties of the United States. Every such license shall provide that the President of the United States may, in time of war or public peril, cause the closing of any wireless apparatus station and the removal therefrom of all wireless telegraphic apparatus, or authorize the use and control of any such station or apparatus by any department of the Government.

SECTION 3. For the purpose of preventing or minimizing interference between naval and military wireless telegraph stations and the private or commercial wireless telegraph stations in bona fide operation at the time of the passage of this Act, the President of the United States shall establish regulations to govern said private or commercial stations, which may be granted licenses in accordance therewith, and such regulations shall have the force and effect of the law and be enforced by the Secretary of Commerce and Labor as other regulations herein provided for.

SECTION 4. Every license granted under the provisions of this Act for the operation or use of wireless telegraph apparatus in any station which may be established after the passage of this Act, shall be on the condition that the said operation or use thereof shall not interfere with any naval or military wireless telegraph station; and a license to use any wireless telegraphic apparatus previously granted shall be liable to revocation by the Secretary of Commerce and Labor upon the production of evidence satisfactory to him of the fact of such interference. An appeal as to both law and fact from the order or decision of the Secretary of Commerce and Labor in any case involving the right of any person or corporation to obtain or retain a license shall lie to the Circuit Court of Appeals of the jurisdiction in which such person resides or such corporation is formed, as in case of other appeals to the said court from the Circuit Courts of the United States.

SECTION 5. The Secretary of Commerce and Labor shall have power to make regulations prescribing the form and manner in which applications for licenses under this Act shall be made and respecting the granting of such licenses, and regulations otherwise suitable to secure the due execution of the provisions of this Act, and from time to time to add to, modify, amend or revoke such regulations as in his judgment may seen expedient; and such regulations when so adopted shall have the force and effect of law.

Section 6. Licenses may be granted under this Act for the use and operation of wireless telegraphic apparatus at fixed stations upon the mainland, islands, or the navigable waters of the United States, to be known as licenses of the first class, and upon vessels of the United States engaged in interstate or foreign commerce, to be known as licenses of the second class; that the fee for licenses of the first class shall be one hundred dollars for each station, and that the fee for licenses of the second class shall be five hundred dollars for each vessel equipped for the use and operation of wireless telegraphy; but no fee shall be required for any license granted for the conduct of experiments in wireless telegraphy. All fees for licenses shall be turned into the Treasury of the United States and a statement of all those collected in each fiscal year shall be reported to Congress.

Section 7. The expression "wireless telegraph" as used in this Act means any system of electrical communication by telegraphy without the aid of any wire connecting the points from, and to which, the messages, signals or other communications are sent or received.

Section 8. It shall be the duty of every person or corporation using or operating a wireless telegraph pursuant to a license granted under this Act to answer wireless calls and signals from and for any other person or corporation so licensed to receive all messages or signals tendered for transmission to any other neighboring or connecting apparatus, at the price customarily asked and received for such service, to transmit the same to such neighboring or connecting apparatus without discrimination and without regard to the system of telegraphy by which such calls, signals, or messages are made; and a neglect or refusal to observe the requirements of this section when practicable, shall be cause for revocation of license.

Section 9. Any person or corporation who shall willfully or maliciously interfere with the sending or receiving of wireless telegraphic messages or signals by or on behalf of the Government of the United States, or by any person or corporation using or operating wireless telegraph instrument pursuant of a license granted under this Act shall be guilty of a misdemeanour, and on conviction thereof shall be punished for every such offense by a fine of not exceeding five hundred dollars, or by imprisonment for a period not exceeding twelve months or by both.

Section 10. A person or corporation shall not use or operate any apparatus for wireless telegraphy on a foreign ship whilst that ship is in territorial waters of the United States otherwise than in accordance with the regulations made for that purpose by the Secretary of Commerce and Labor and any breach of any such regulations will make the offender liable to a penalty not to exceed fifty (50.00) dollars for each offense and to the forfeitures of any apparatus for wireless telegraphy installed or worked on such ships. Save as aforesaid nothing in this Act shall apply to the working of apparatus for wireless telegraphy installed in any foreign ship.

Section 11. Any wireless telegraph station owned and operated by a department of the Government shall not compete for commercial messages with licensed telegraph stations.

Section 12. This Act shall take effect and be in force on and after the first day of July, nineteen hundred and five; provided, however, that the third and fourth sections of this Act shall take effect and be in force at the time of its passage.

Appendix E. Special Notice to Mariners No. 47a

Published by the HYDROGRAPHIC OFFICE
R. H. McLean *Editor*
Washington, D.C., *November* 22, 1904

(1681) U. S. Naval Wireless Telegraph Service
The following regulations governing the use of the U.S. Naval Coastwise Wireless Telegraph Stations are hereby established:

1. The facilities of the naval coastwise wireless telegraph stations (including the one on the Nantucket Shoal Lightship), for communicating with ships at sea, where not in competition with private wireless telegraph stations, are placed at the service of the public generally and of maritime interests in particular under the rules established herein, which are subject to modification from time to time, for the purpose of:

(a) Reporting vessels and intelligence received by wireless telegraphy with regard to maritime casualties, derelicts at sea and overdue vessels.

(b) Receiving wireless telegrams of a private or commercial nature from ships at sea, for further transmission by telegraph or telephone lines.

(c) Transmitting wireless telegrams to ships at sea.

2. For the present, this service will be rendered free. All messages will, however, be subject to the tariffs of the ship stations and landlines. Arrangements have been made with both the Western Union and Postal Telegraph Companies for forwarding messages received from ships at sea. When a message is not prepaid the company delivering it will collect the charges. Ship owners should arrange with companies operating the landlines as to tariffs and the settlement therefor. Messages will not be accepted for transmission to ships whose owners have not agreed to accept unpaid messages, unless a sufficient sum is deposited to cover all charges.

3. The Nantucket Shoal Lightship Station will report vessels and transmit messages from them if the signals are made by the International Code, or any other known to the operators on the lightship.

4. When notified by the Weather Bureau of the Department of Agriculture, Naval wireless telegraph stations will give storm warnings to vessels communicating with them by wireless telegraphy. Storm warnings will soon be sent to the Nantucket Shoal Lightship by wireless telegraphy and storm signals furnished by the Weather Bureau will be displayed therefrom to warn passing vessels.

5. All vessels having the use of the naval wireless telegraph service are requested to take daily meteorological observations of the weather when within communicating range and to transmit such observations to the Weather Bureau by wireless telegraphy at least once daily, and transmit observations oftener when there is a marked change in the barometer.

6. Arrangements for a time signal service by wireless telegraphy are now being made.

7. All ship owners desiring to use any special code of signals for communicating with the Nantucket Shoal Lightship Station or any of the shore stations, or make any other special arrangements are requested to communicate with the Bureau of Equipment, Navy Department, Washington, D.C.

8. All Chambers of Commerce, Maritime Exchanges, newspapers, news agencies, and others desiring to have vessel reports and general marine news forwarded to them regularly are requested to communicate with the Bureau of Equipment in order that necessary arrangements for the service may be made. In no case will an operator attached to a station be allowed to act as an agent for any individual or corporation, but all vessel reports and marine news not of a private nature will be supplied to all applicants, so long as this service does not too greatly tax the personnel of the stations, when it will be necessary for those desiring information invoving much time for its distribution to appoint agents who will be allowed access to the station bulletins.

9. Naval wireless telegraph stations are equipped with apparatus of several system and can communicate with all the principal wireless telegraph systems now in use, if tuned to the same wave length. The department is desirous of cooperating with all ship owners wishing to avail themselves of its wireless telegraph service, and, judging from its experience with numerous systems, it is believed that there will be little or no difficulty in arranging for communication between its stations and ships equipped with apparatus of other systems, if the owners of the apparatus as well as the owners of the ships are desirous of establishing such communication.

10. Vessels desiring to make use of this service regularly must agree to transmit and receive all Government messages free.

The following stations are fully manned and will be prepared to receive messages at all hours, except in case of some accidental breakdown, which is not apt to occur because of the precautionary measures which have been taken.

The call letter is given in the column opposite the name of each station:

Stations	*Call letter*
Navy Yard, Portsmouth, N.H.	PC
Cape Ann, (Thatchers Island)	PE
Highland Light, Cape Cod, Mass.	PH
Nantucket Shoal Lightship	PI
Torpedo Station, Newport, R.I.	PK
Montauk Point, L.I.	PR
Navy Yard, New York	PT
Highlands of Navesink, N.J.	PV
Cape Henry, Va.	QN
Navy Yard, Norfolk, Va.	QL
Dry Tortugas, Fla.	RF
San Juan, P. R.	SA
Culebra, West Indies	SD
Yerba Buena Island, Calif.	TI
Navy Yard, Mare Island, Calif.	TG

It is expected that the following stations will be in operation in a few weeks fully manned to receive messages at all hours:

Stations	*Call letter*
Cape Elizabeth, Maine	PA
Navy Yard, Boston, Mass.	PG
Naval Station, Key West, Fla.	RD
Navy Yard, Pensacola, Fla.	RK
Naval Station, Guantanamo, Cuba	SI
Panama Canal Zone	SL
Farallon Island, Calif.	TH
Naval Station, Cavite, Philippine Islands	UT
Cabra Island, Philippine Islands	UY

The following stations are equipped with apparatus, but are not yet fully manned; they will receive and transmit messages when operators are on duty:

Stations	*Call letter*
Naval Academy, Annapolis, Md.	QG
Navy Yard, Washington, D.C.	QI

The Bureau of Equipment expects to erect wireless telegraph stations at the principal points along the cost of the United States and at points in its insular possessions. As fas as they are completed they will be open for public use under the regulations established herein.

Notice will be given in the "Notice to Mariners" when stations are put in operation or withdrawn from the service for any reason.

Messages for the Cape Ann station should be forwarded via the Navy Yard, Portsmouth, N.H.

The Nantucket Shoal Lightship will transmit its messages to the Torpedo Station, Newport, R. I. All messages intended to be sent via this lightship to ships at sea should be sent to the Torpedo Station.

Messages for the Montauk Point wireless telegraph station will also be sent via the Torpedo Station, Newport, R.I.

Arrangements have been made with the Weather Bureau for the transmission of messages between Cape Henry wireless telegraph station and Norfolk. All messages intended for the Cape Henry station should be sent via the Weather Bureau, Norfolk, Va.

All messages intended for Dry Tortugas should be sent via the Naval Station, Key West, Fla.

The station at Yerba Buena, Calif., can be reached by either the Postal Telegraph or the Western Union system and the one at Mare Island by the Western Union.

The Farallon station will communicate with Yerba Buena Island, Calif.

INSTRUCTIONS TO GOVERN COMMUNICATION BY WIRELESS TELEGRAPHY BETWEEN WIRELESS TELEGRAPH STATIONS AND SHIPS

I. A vessel wishing to communicate with a station and having ascertained by "listening in" that she is not interfering with messages being exchanged within her range should make the call letter of the station at a distance not greater than 75 miles from it.

II. The call should not be continuous, but should be at intervals of about three minutes in order to give the station a chance to answer.

III. After the station answers the vessel should send her name, distance from station, weather and number of words she wishes to send; then stop until the station makes O.K., signals the number of words she wishes to send to vessel and signals go ahead.

IV. Then the vessel begins to send new messages, stopping at the end of each 50 words and waiting until the station signals O.K. and go ahead; when all messages have been sent she will so indicate. If the sender desires to designate the Western Union or Postal Telegraph system for further transmission of his message he should do so immediately after the address, as for example: "A. B. C., Washington, D.C., via W.U. (or P.T.)."

V. When a vessel has indicated that she has finished the station will send to the vessel such messages as she may have for her in the following order:

(a) Government business, viz, telegrams from any Government departments to their agents on board.

(b) Business concerning the vessel with which communication has been established, viz, telegrams from owner to master.

(c) Urgent private dispatches, limited.

(d) Press dispatches.

(e) Other dispatches.

VI. In the case of the Nantucket Shoal Lightship, it will, immediately on receiving the vessel's call, acknowledge, and (after receiving vessel's name, distance, weather report, and number of words she wishes to send) transmit the first three to Newport, and then tell the vessel to go ahead with her messages.

VII. After receiving these and sending the vessel any messages on file for her, the lightship will transmit to Newport messages received from the communicating vessel in the following order:

(a) Government business.

(b) Urgent private dispatches, limited.

(c) Press dispatches.

(d) Other dispatches.

VIII. A naval wireless telegraph station has the right to break in on any message being sent by a vessel at any time, and the right of way may be given at any time to a government vessel or one in distress.

IX. When two or more vessels desire to communicate with a naval wireless telegraph station at the same time, the one whose call is first received will have right of way, and the others will be told to wait and will be taken up in turn. Vessels having been told to wait must cease calling.

X. In case communication is not established with any ship for which messages are on file, the naval wireless telegraph station will notify the telegraph company from which the messages were received, giving sufficient information for them to identify the telegrams and notify the sender.

XI. In order to obtain the best results, both sending and receiving apparatus should be tuned to wave length of 320 meters.

XII. Until further notice the speed of sending should not exceed 12 words per minute.

XIII. In order that all messages received at naval wireless telegraph stations may be forwarded to ships for which they are intended, and in order that all ships equipped with wireless telegraph apparatus may receive storm warnings, they should always report when in signaling distance of a naval wireless telegraph station.

XIV. The service being without charge at present, the government accepts no responsibility for the reception or transmission of messages from or for passing vessels. Every effort will be made to transmit all messages without error and as expeditiously as possible. It must be remembered that errors are not uncommon in ordinary telegraph and cable messages, so that due allowance should be made.

XV. In order that the service may be made as good and as useful as possible, it is requested that complaints should be promptly reported to the Bureau of Equipment as soon as possible after the cause therefor, giving date, hour and other details, to enable the Bureau to investigate the case.

XVI. Information regarding the Naval Wireless Telegraph Service will be published in "Notice to Mariners."

(Special N.M. 47a, 1904.)

Appendix F. Convention Adopted by Second International Radio Telegraphic Conference, Berlin, Germany, 1906

INTERNATIONAL WIRELESS TELEGRAPH CONVENTION CONCLUDED BETWEEN GERMANY, THE UNITED STATES OF AMERICA, ARGENTINA, AUSTRIA, HUNGARY, BELGIUM, BRAZIL, BULGARIA, CHILE, DENMARK, SPAIN, FRANCE, GREAT BRITAIN, GREECE, ITALY, JAPAN, MEXICO, MONACO, NORWAY, THE NETHERLANDS, PERSIA, PORTUGAL, ROUMANIA, RUSSIA, SWEDEN, TURKEY AND URUGUAY

The undersigned, plenipotentiaries of the Governments of the countries enumerated above, baving met in conference at Berlin, have agreed on the following Convention, subject to ratification:

ARTICLE 1

The High Contracting Parties bind themselves to apply the provisions of the present Convention to all wireless telegraph stations open to public service between the coast and vessels at sea—both coastal stations and stations on shipboard—which are established or worked by the Contracting Parties.

They further bind themselves to make the observance of these provisions obligatory upon private enterprises authorized either to establish or work coastal stations for wireless telegraphy open to the service of public correspondence between the coast and vessels at sea, or to establish or work wireless telegraph stations, whether open to general public service or not, on board of vessels flying their flag.

ARTICLE 2

By "coastal stations" is to be understood every wireless telegraph station established on shore or on board a permanently moored vessel used for the exchange of correspondence with ships at sea.

Every wireless telegraph station established on board any vessel not permanently moored is called a "station on shipboard."

ARTICLE 3

The coastal stations and the stations on shipboard shall be bound to exchange wireless telegrams reciprocally without distinction of the wireless telegraph system adopted by such stations.

ARTICLE 4

Notwithstanding the provisions of Article 3, a station may be reserved for a limited public service determined by the object of the correspondence or by other circumstances independent of the system employed.

ARTICLE 5

Each of the High Contracting Parties undertakes to connect the coastal stations to the telegraph system by special wires, or, at least, to take other measures which will insure a rapid exchange between the coastal stations and the telegraph system.

ARTICLE 6

The High Contracting Parties shall notify one another of the names of coastal stations and stations on shipboard referred to in Article 1, and also of all data, necessary to facilitate and accelerate the exchange of wireless telegrams, as specified in the Regulations.

ARTICLE 7

Each of the High Contracting Parties reserves the right to prescribe or permit at the stations referred to in Article 1, apart from the installation the data of which are to be published in conformity with Article 6, the installation and working of other devices for the purpose of establishing special wireless communication without publishing the details of such devices.

ARTICLE 8

The working of the wireless telegraph stations shall be organized as far as possible in such manner as not to disturb the service of other wireless stations.

ARTICLE 9

Wireless telegraph stations are bound to give absolute priority to calls of distress from ships, to similarly answer such calls and to take such action with regard thereto as may be required.

ARTICLE 10

The total charge for wireless telegrams shall comprise:

1. The charge for the maritime transmission, that is:

   (a) The coastal rate, which shall fall to the coastal station;

   (b) The shipboard rate, which shall fall to the shipboard station.

2. The charge for transmission over the lines of the telegraph system, to be computed according to the general regulations.

The coastal rate shall be subject to the approval of the Government of which the coastal station is dependent, and the shipboard rate to the approval of the Government whose flag the ship is flying.

Each of these rates shall be fixed in accordance with the tariff per word, pure and simple, with an optional minimum rate per wireless telegram, on the basis of an equitable remuneration for wireless work. Neither rate shall exceed a maximum to be fixed by the High Contracting Parties.

However, each of the High Contracting Parties shall be at liberty to authorize higher rates than such maximum in the case of stations of ranges exceeding 800 km. or of stations whose work is exceptionally difficult owing to physical conditions in connection with the installation or working of the same.

For wireless telegrams proceeding from or destined for a country and exchanged directly with the coastal stations of such country, the High Contracting Parties shall advise one another of the rates applicable to the transmission over the lines of their telegraph system. Such rates shall be those resulting from the principle that the coastal station is to be considered as the station of origin or of destination.

ARTICLE 11

The provisions of the present Convention are supplemented by Regulations, which shall have the same force and go into effect at the same time as the Convention.

The provisions of the present Convention and of the Regulations relating thereto may at any time be modified by the High Contracting Parties by common consent. Conferences of plenipotentiaries or simply administrative conferences, according as the Convention or the Regulations are affected, shall take place from time to time; each conference shall fix the time and place of the next meeting.

ARTICLE 12

Such conferences shall be composed of delegates of the Governments of the contracting countries.

In the deliberations each country shall have but one vote.

If a Government adheres to the Convention for its colonies, possessions or protectorates, subsequent conferences may decide that such colonies, possessions or protectorates, or a part thereof, shall be considered as forming a country as regards the application of the preceding paragraph. But the number of votes at the disposal of one Government, including its colonies, possessions or protectorates, shall in no case exceed six.

ARTICLE 13

An International Bureau shall be charged with collecting, coordinating and publishing information of every kind relating to wireless telegraphy, examining the applications for changes in the Convention or Regulations, promulgating the amendments adopted, and generally performing all administrative work referred to it in the interest of international wireless telegraphy.

The expenses of such institution shall be borne by all the contracting countries.

ARTICLE 14

Each of the High Contracting Parties reserves to itself the right of fixing the terms on which it will receive wireless telegrams proceeding from or intended for any station, whether on shipboard or coastal, which is not subject to the provisions of the present Convention.

If a wireless telegram is received the ordinary rates shall be applicable to it.

Any wireless telegram proceeding from a station on shipboard and received by a coastal station of a contracting country, or accepted in transit by the administration of a contracting country, shall be forwarded.

Any wireless telegram intended for a vessel shall also be forwarded if the administration of the contracting country has accepted it originally or in transit from a non-contracting country, the coastal station reserving the right to refuse transmission to a station on shipboard subject to a non-contracting country.

ARTICLE 15

The provisions of Articles 8 and 9 of this Convention are also applicable to wireless telegraph installations other than those referred to in Article 1.

ARTICLE 16

Governments which are not parties to the present Convention shall be permitted to adhere to it upon their request. Such adherence shall be communicated through diplomatic channels to the contracting Government in whose territory the last conference shall have been held, and by the latter to the remaining Governments.

The adherence shall carry with it to the fullest extent acceptance of all the clauses of this Convention and admission to all the advantages stipulated therein.

ARTICLE 17*

The provisions of Articles 1, 2, 3, 5, 6, 7, 8, 11, 12 and 17 of the International Telegraph Convention of St. Petersburg of July 10/22, 1875, shall be applicable to international wireless telegraphy.

*See translation of Articles of the International Telegraph Convention referred to in Article 17, appended hereto.

ARTICLE 18

In case of disagreement between two or more contracting Governments regarding the interpretation or execution of the present Convention or of the Regulations referred to in Article 11, the question in dispute may, by mutual agreement, be submitted to arbitration. In such case each of the Governments concerned shall choose another Government not interested in the question at issue.

The decision of the arbiters shall be arrived at by the absolute majority of votes.

In case of a division of votes, the arbiters shall choose, for the purpose of settling the disagreement, another contracting Government which is likewise a stranger to the question at issue. In case of failure to agree on a choice, each arbiter shall propose a disinterested contracting Government, and lots shall be drawn between the Governments proposed. The drawing of the lots shall fall to the Government within whose territory the international bureau provided for in Article 13 shall be located.

ARTICLE 19

The High Contracting Parties bind themselves to take, or propose to their respective legislatures, the necessary measures for insuring the execution of the present Convention.

ARTICLE 20

The High Contracting Parties shall communicate to one another any laws already framed, or which may be framed, in their respective countries relative to the object of the present Convention.

ARTICLE 21

The High Contracting Parties shall preserve their entire liberty as regards wireless telegraph installations other than provided for in Article 1, especially naval and military installations, which shall be subject only to the obligations provided for in Articles 8 and 9 of the present Convention.

However, when such installations are used for general public service they shall conform, in the execution of such service, to the provisions of the Regulations as regards the mode of transmission and rates.

ARTICLE 22

The present Convention shall go into effect on the 1st day of July, 1908, and shall remain in force for an indefinite period or until the expiration of one year from the day when it shall be denounced by any of the contracting parties.

Such denunciation shall affect only the Government in whose name it shall have been made. As regards the other Contracting Powers, the Convention shall remain in force.

ARTICLE 23

The present Convention shall be ratified and the ratifications exchanged at Berlin with the least possible delay.

In witness whereof the respective plenipotentiaries have signed one copy of the Convention, which shall be deposited in the archives of the Imperial Government of Germany, and a copy of which shall be transmitted to each Party.

Done at Berlin, November 3, 1906.

For Germany:
KRAETKE
SYDOW
For United States:
CHARLEMAGNE TOWER
H. N. MANNEY
JAMES ALLEN
JOHN I. WATERBURY
For Argentina:
J. OIMI
For Austria:
BARTH
FRIES

For Hungary:
PIERRE DE SZALAY
DR. DE HENNYEY
HOLLOS
For Belgium:
F. DELARGE
E. BUELS
For Brazil:
CESAR DE CAMPOS
For Bulgaria:
I. STOYANOVITCH
For Chile:
J. MUNOZ HURTADO
J. MERY

For Denmark:
N. R. MEYER
I. A. VOEHTZ
For Spain:
IGNACIO MURCIA
RAMON ESTRADA
RAFAEL RAVENA
ISIDRO CALVO
MANUEL NORIEGA
ANTONIO PELAEZ-CAMPOMANES
For Russia:
A. EICHHOIZ
A. EULER

For Russia—Continued
VICTOR BILIBINE
A. REMMERT
W. KEDRINE

For Sweden:
HERMAN RYDIN
A. HAMILTON

For France:
J. BORDELONGUE
L. GASHARD
BOULANGER
A. DEVOS

For Great Britain:
H. BABINGTON SMITH
A. E. BETHELL
R. L. HIPPISLEY

For Greece:
T. ARGYROPOULOS

For Italy:
J. COLOMBO

For Japan:
OSUKE ASANO
ROKURE YASHIRO
SHUNKICHI KIMURA
ZIRO TANAKA
SABURO HYAKUTAKE

For Mexico:
JOSE M. PEREZ

For Monaco:
J. DEPELLEY

For Norway:
HEFTYE
O. T. EIDEM

For Netherlands:
KRUYT
PEREK
HOVEN

For Persia:
HOVHANNES KHAN

For Portugal:
PAULO BENJAMIN CABRAL

For Roumania:
GR. CERKEZ

For Turkey:
NAZIF BEY

For Uruguay:
F. A. COSTANZO

SUPPLEMENTARY AGREEMENT

The undersigned plenipotentiaries of the Governments of Germany, the United States of America, Argentina, Austria, Hungary, Belgium, Brazil, Bulgaria, Chile, Denmark, Spain, France, Greece, Monaco, Norway, the Netherlands, Roumania, Russia, Sweden, Turkey, and Uruguay bind themselves mutually, from the date of the going into effect of the Convention, to conform to the provisions of the following supplementary articles:

I. Each station on shipboard referred to in Article 1 of the Convention shall be bound to correspond with any other station on shipboard without distinction of the wireless telegraph system adopted by such stations respectively.

II. The Governments which have not adhered to the foregoing article may at any time signify, by following the procedure prescribed by Article 16 of the Convention, that they bind themselves to conform to its provisions.

Those which have adhered to the foregoing article may at any time, under the same conditions as provided for in Article 22, signify their intention to cease conforming to its provisions.

III. This agreement shall be ratified and the ratifications exchanged at Berlin with the least possible delay.

In witness whereof the respective plenipotentiaries have signed one copy of the present Agreement, which shall be deposited in the archives of the Imperial Government of Germany, and a copy of which shall be transmitted to each of the Parties.

Done at Berlin, November 3, 1906.

For Germany:
KRAETKE
SYDOW

For United States:
CHARLEMAGNE TOWER
H. N. MANNEY
JAMES ALLEN
JOHN I. WATERBURY

For Argentina:
J. OIMI

For Austria:
BARTH
FRIES

For Denmark:
N. R. MEYER
I. A. VOEHITZ

For Spain:
IGNACIO MURCIA
RAMON ESTRADA
RAFAEL RAVENA
ISIDRO CALVO
MANUEL NOREIGA
ANTONIO PELAEZ-CAMPOMANES

For France:
J. BORDELONGUE
L. GASCHARD
BOULANGER
A. DEVOS

For Greece:
T. ARGYROPOULOS

For Monaco:
J. DEPELLEY

For Norway:
HEFTYE
O. T. EIDEM

For Hungary:
PIERRE DE SZALAY
DR. DE HENNYEY
HOLLOS

For Belgium:
F. DELARGE
E. BUELS

For Brazil:
CESAR DE CAMPOS

For Bulgaria:
I. STOYANOVITCH

For Chile:
J. MUNOZ HURTADO
J. MERY

For Netherlands:
KRUYT
PERK
HOVEN

For Roumania:
GR. CERKEZ

For Russia:
A. EICHOLZ
A. EULER
VICTOR BILIBINE
A. REMMERT
W. KEDRINE

For Sweden:
HERMAN RYDIN
A. HAMILTON

For Turkey:
NAZIF BEY

For Uruguay:
F. A. COSTANZO

FINAL PROTOCOL

At the moment of signing the Convention adopted by the International Wireless Telegraph Conference of Berlin, the undersigned plenipotentiaries have agreed as follows:

I. The High Contracting Parties agree that at the next Conference the number of votes to which each country is entitled (Article 12 of the Convention) shall be decided at the beginning of the deliberations, so that the colonies, possessions or protectorates admitted to the privilege of voting may exercise their right to vote during the entire course of the proceedings of such Conference.

This decision shall be of immediate effect and remain in force until amended by a subsequent Conference.

As regards the next Conference, applications for the admission of new votes in favor of colonies, possessions or protectorates which may have adhered to the Convention shall be addressed to the International Bureau at least six months prior to the date of the convening of such Conference. Notice of such applications shall at once be given to the remaining contracting Governments, which may, within the period of two months from the receipt of the notice, formulate similar applications.

II. Each contracting Government may reserve the right to designate, according to circumstances, certain coastal stations to be exempted from the obligation imposed by Article 3 of the Convention, provided that, as soon as this measure goes into effect, there shall be opened within its territory one or several stations subject to the obligations of Article 3, insuring, within the region where the exempted stations are located, such wireless telegraph service as will satisfy the needs of the public service. The Governments desiring to reserve this right shall give notice thereof in the form provided for in the second paragraph of Article 16 of the Convention, not later than three months before the Convention goes into effect, or, in case of subsequent adhesion, at the time of such adhesion.

The countries whose names follow below declare now that they will not reserve such right:

Belgium	Mexico
Brazil	Monaco
Bulgaria	Norway
Chili	Netherlands
Greece	Roumania
Germany	Russia
United States	Sweden
Argentina	Uruguay
Austria	
Hungary	

III. The manner of carrying out the provisions of the foregoing article shall be at the discretion of the Government which takes advantage of the right of exemption; such Government shall be at liberty to decide from time to time, in its own judgment, how many stations and what stations shall be exempted. Such Government shall likewise be at liberty as regards the manner of carrying out the provision relative to the opening of other stations subject to the obligations of Article 3, insuring, within the region where the exempted stations are located, such wireless telegraph service as will satisfy the needs of the public service.

IV. It is understood that, in order not to impede scientific progress, the provisions of Article 3 of the Convention shall not prevent the eventual employment of a wireless telegraph system incapable of communicating with other systems, provided, however, that such incapacity shall be due to the specific nature of such system and that it shall not be the result of devices adopted for the sole purpose of preventing intercommunication.

V. The adherence to the Convention by the Government of a country having colonies, possessions or protectorates shall not carry with it the adherence of its colonies, possessions or protectorates, unless a declaration to that effect is made by such Government. Such colonies, possessions and protectorates as a whole, or each of them separately, may form the subject of a separate adherence or a separate denunciation within the provisions of Articles 16 and 22 of the Convention.

It is understood that the stations on board of vessels whose headquarters is a port in a colony, possession or protectorate may be deemed as subject to the authority of such colony, possession or protectorate.

VI. Note is taken of the following declaration:

The Italian delegation in signing the Convention does so with the reservation that the Convention can not be ratified on the part of Italy until the date of the expiration of her contracts with Mr. Marconi and his Company, or at an earlier date if the Government of the King of Italy shall succeed in fixing such date by negotiations with Mr. Marconi and his Company.

VII. In case one or several of the High Contracting parties shall not ratify the Convention, it shall nevertheless be valid as to the parties which shall have ratified it.

In witness whereof the undersigned plenipotentiaries have drawn up the present Final Protocol, which shall be of the same force and effect as though the provisions thereof had been embodied in the text of the Convention itself to which it has reference, and they have signed one copy of the same, which shall be deposited in the archives of the Imperial Government of Germany, and a copy of which shall be transmitted to each of the parties.

Done at Berlin, November 3, 1906.

For Germany:
KRAETKE
SYDOW
For United States:
CHARLEMAGNE TOWER
H. N. MANNEY
JAMES ALLEN
JOHN I. WATERBURY
For Argentina:
J. OLMI
For Austria:
BARTH
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For Denmark:
N. R. MEYER
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ANTONIO PELAEZ-CAMPOMANES
For Hungary:
PIERRE DE SZALAY
DR. DE HENNYEY
HOLLOS

For Belgium:
F. DELARGE
E. BUELS
For Brazil:
CESAR DE CAMPOS
For Bulgaria:
I. V. STOYANOVITCH
For Chile:
J. MUNOZ HURTADO
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For Monaco:
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For Greece:
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For Italy:
J. COLOMBO
For Japan:
OSUKE ASANO
ROKURE YASHIRO
SHUNKICHI KIMURA
ZIRO TANAKA
SABURO HYAKUTAKE
For Mexico:
JOSE M. PEREZ
For Persia:
HOVHANNES KHAN
For Portugal:
PAULO BENJAMIN CABRAL
For Roumania:
GR. CERKEZ
For Russia:
A. EICHOIZ
A. EULER
VICTOR BILIBINE
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SERVICE REGULATIONS ANNEXED TO THE INTERNATIONAL WIRELESS TELEGRAPH CONVENTION

1. ORGANIZATION OF WIRELESS TELEGRAPH STATIONS

I. The choice of wireless apparatus and devices to be used by the coastal stations and stations on shipboard shall be unrestricted. The installation of such stations shall as far as possible keep pace with scientific and technical progress.

II. Two wave lengths, one of 300 meters and the other of 600 meters, are authorized for general public service. Every coastal station opened to such service shall use one or the other of these two wave lengths. During the whole time that the station is open to service it shall be in condition to receive calls according to its wave length, and no other wave length shall be used by it for the service of general public correspondence. Each Government may, however, authorize in coastal stations the employment of other wave lengths designed to insure long-range service or any service other than for general public correspondence established in conformity with the provisions of the Convention, provided such wave lengths do not exceed 600 meters or that they do exceed 1,600 meters.

III. 1. The normal wave length for stations on shipboard shall be 300 meters. Every station on shipboard shall be installed in such manner as to be able to use this wave length. Other wave lengths may be employed by such stations provided they do not exceed 600 meters.

2. Vessels of small tonnage which are unable to have plants on board insuring a wave length of 300 meters may be authorized to use a shorter wave length.

IV. 1. The International Bureau shall be charged with drawing up a list of wireless telegraph stations of the class referred to in Article 1 of the Convention. Such list shall contain for each station the following data:

(1) Name, nationality, and geographical location in the case of coastal stations; name, nationality, distinguishing signal of the International Code and name of ship's home port in the case of stations on shipboard:

(2) Call letters (the calls shall be distinguishable from one another and each must be formed of a group of three letters);

(3) Normal range;

(4) Wireless telegraph system;

(5) Class of receiving apparatus (recording, acoustic, or other apparatus);

(6) Wave lengths used by the station (normal wave length to be underscored);

(7) Nature of service carried on by the station;

General public correspondence;

Limited public correspondence (correspondence with vessels; correspondence with shipping lines; correspondence with ships fitted with apparatus of the . . . system, etc.);

Long-range public correspondence;

Correspondence of private interest;

Special correspondence (exclusively official correspondence); etc.

(8) Hours during which the station is open.

(9) Coastal rate or shipboard rate.

2. The list shall also contain such data relating to wireless telegraph stations other than those specified in Article 1 of the Convention as may be communicated to the International Bureau by the Management of the Wireless Telegraph Service ("Administration") to which such stations are subject.

V. The exchange of superfluous signals and words is prohibited to stations of the class referred to in Article 1 of the Convention. Experiments and practice will be permitted in such stations insofar as they do not interfere with the service of other stations.

VI. 1. No station on shipboard shall be established or worked by private enterprise without authority from the Government to which the vessel is subject. Such authority shall be in the nature of a license issued by said Government.

2. Every station on shipboard that has been so authorized shall comply with the following requirements:

(a) The system employed shall be a syntonized system;

(b) The rate of transmission and reception, under normal conditions, shall not be less than twelve words a minute, words to be counted at the rate of five letters each;

(c) The power transmitted to the wireless telegraph apparatus shall not, under normal conditions, exceed one-kilowatt. Power exceeding one kilowatt may be employed when the vessel finds it necessary to correspond while more than 300 kilometers distant from the nearest coastal station, or when, owing to obstructions, communication can be established only by means of an increase of power.

3. The service of the station on shipboard shall be carried on by a telegraph operator holding a certificate issued by the Government to which the vessel is subject. Such certificate shall attest the professional efficiency of the operator as regards:

(a) Adjustment of the apparatus;

(b) Transmission and acoustic reception at the rate of not less than 20 words a minute;

(c) Knowledge of the regulations governing the exchange of wireless telegraph correspondence.

4. The certificate shall furthermore state that the Government has bound the operator to secrecy with regard to the correspondence.

VII. 1. If the management of the wireless telegraph service of a country has knowledge of any infraction of the Convention or of the Regulations committed in any of the stations authorized by it, it shall ascertain the facts and fix the responsibility.

In the case of stations on shipboard, if the operator is responsible for such infraction, the management of the wireless telegraph service shall take the necessary measures and, if the necessity should arise, withdraw the certificate. If it is ascertained that the infraction is the result of the condition of the apparatus or of instructions given the operator, the same method shall be pursued with regard to the license issued to the vessel.

2. In cases of repeated infractions chargeable to the same vessel, if the representations made to the wireless telegraph management of the country to which the vessel is subject by that of another country remain without effect, the latter shall be at liberty, after giving due notice, to authorize its coastal stations not to accept communications proceeding from he vessel at fault. In case of disagreement between the managements of the wireless telegraph service of two countries, the question shall be submitted to arbitration at the request of either of the two Governments at issue. The procedure in such case shall be the same as indicated in Article 8 of the Convention.

2. HOURS OF SERVICE OF COASTAL STATIONS

VIII. 1. The service of coastal stations shall, as far as possible, be constant, day and night, without interruption.

Certain coastal stations, however, may have a service of limited duration. The management of the wireless telegraph service of each country shall fix the hours of service.

2. The coastal stations whose service is not constant shall not close before having transmitted all their wireless telegrams to the vessels which are within their radius of action, nor before having received from such vessels all the wireless telegrams of which notice has been given. This provision is likewise applicable when vessels signal their presence before the actual cessation of work.

3. FORM AND POSTING OF WIRELESS TELEGRAMS

IX. If the route of a wireless telegram is partly over telegraph lines, or through wireless telegraph stations subject to a noncontracting Government, such telegram may be transmitted provided the managements of the wireless telegraph service to which such lines or stations are subject have declared that, if the occasion should arise, they will comply with such provisions of the Convention and of the Regulations as are indispensable to the regular transmission of wireless telegrams and that the payment of charges is insured.

1. Wireless telegrams shall show in the preamble that the service is "wireless" ("radio").

2. In the transmission of wireless telegrams of shipboard stations to coastal stations, the date and hour of posting may be omitted in the preamble.

Upon reforwarding a wireless telegram over the telegraph system, the coastal station shall show thereon its own name as the office of origin, followed by that of the vessel, and shall state, as the hour of posting, the hour when the telegram was received by it.

XI. The address of wireless telegrams intended for ships at sea shall be as complete as possible. It shall embrace the following:

(a) The name of the addressee, with additional designations if any;

(b) The name of the vessel as it appears in the list, supplemented by her nationality and, if necessary, by her distinguishing signal of the International Code, in case there are several vessels of the same name;

(c) The name of the coastal station as it appears in the list.

4. RATES

XII. The coastal rate shall not exceed 60 centimes (11.6 cents) a word, and the shipboard rate shall not exceed 40 centimes (7.7 cents) a word.

A minimum rate per telegram, not to exceed the coastal rate or shipboard rate for a wireless telegram of ten words, may be imposed as coastal or shipboard rate.

XIII. The country within whose territory a coastal station is established which serves as intermediary for the exchange of wireless telegrams between a station on board ship and another country shall be considered, so far as the application of telegraph rates is concerned, as the country of origin or of destination of such telegrams, and not as the country of transit.

5. COLLECTION OF CHARGES

XIV. The total charge for wireless telegrams shall be collected of the sender.

Stations on shipboard shall to that end have the necessary tariffs. They shall be at liberty, however, to obtain information from coastal stations on the subject of rates for wireless telegrams for which they do not possess all the necessary data.

6. TRANSMISSION OF WIRELESS TELEGRAMS

A. SIGNALS OF TRANSMISSION

XV. The signals to be employed are those of the Morse International Code.

XVI. Ships in distress shall use the following signal: . . . — — — . . . repeated at brief intervals.

As soon as a station perceives the signal of distress it shall cease all correspondence and not resume it until after it has made sure that the correspondence to which the call for assistance has given rise is terminated.

In case the ship in distress adds at the end of the series of her calls the call letters of a particular station the answer to the call shall be incumbent upon that station alone. If the call for assistance does not specify any particular station, every station perceiving such call shall be bound to answer it.

XVII. 1. The call letters following the letters: .— —. .—. —... "PRB" signify that the vessel or station making the call desires to communicate with the station called by means of the International Signal Code.

The combination of the letters P B R as a service signal for any other purpose than that specified above is prohibited.

2. Wireless telegrams may be framed with the aid of the International Signal Code.

Those addressed to a wireless telegraph station with a view to being forwarded by it are not to be translated by such station.

B. ORDER OF TRANSMISSION

XVII. Between two stations wireless telegrams of the same order shall be transmitted one by one, by the two stations alternately, or in series of several telegrams, as the coastal station may indicate, provided the duration of the transmission of each series does not exceed twenty minutes.

C. METHOD OF CALLING WIRELESS STATIONS AND TRANSMISSION OF WIRELESS TELEGRAMS

XIX. 1. As a general rule, it shall be the shipboard station that calls the coastal station.

2. The call should be made, as a general rule, only when the distance of the vessel from the coastal station is less than 75 percent of the normal range of the latter.

3. Before proceeding to a call, the station on shipboard shall adjust its receiving apparatus to its maximum sensibility and make sure that the coastal

station which it wishes to call up is not in correspondence with any other station. If it finds that any transmission is in progress, it shall wait for the first pause.

4. The shipboard station shall use for calling the normal wave of the coastal station.

5. If in spite of these precautions the public exchange of wireless telegrams is impeded at any place, the call shall cease upon the first request from a coastal station open to public correspondence. The latter station shall in such case indicate the approximate length of time it will be necessary to wait.

XX. 1. The call shall comprise the signal: — . — . — the call letters of the station called repeated three times, the word "from" ("de") followed by the call letters of the sending station repeated three times.

2. The called station shall answer by making the signal: — . — . — followed by the call letters of the corresponding station repeated three times, the word "from," its own call letters, and the signal: — . —

XXI. If a station called does not answer the call (Article XX) repeated three times at intervals of two minutes, the call shall not be resumed until after an interval of half an hour, the station issuing the call having first made sure that no wireless correspondence is in progress.

XXII. 1. As soon as the coastal station has answered, the shipboard station shall make known to it:

(a) The distance of the vessel from the coastal station in nautical miles;

(b) Her true bearing in degrees counted from 0 to 360;

(c) Her true course in degrees counted from 0 to 360;

(d) Her speed in nautical miles;

(e) The number of words she has to transmit.

2. The coastal station shall answer, stating the number of words to be transmitted to the vessel.

3. If the transmission can not take place immediately, the coastal station shall inform the station on shipboard of the approximate length of time that it will be necessary to wait.

XXIII. When a coastal station receives calls from several shipboard stations, the coastal station shall decide the order in which the shipboard stations shall be admitted to exchange their messages.

In fixing this order the coastal station shall be guided exclusively by the necessity of permitting each station concerned to exchange the greatest possible number of wireless telegrams.

XXIV. Before beginning the exchange of correspondence the coastal station shall advise the shipboard station whether the transmission is to be effected in the alternate order or by series (Article XVIII); it shall then begin the transmission or follow up the preliminaries with the signal: — . — (invitation to transmit).

XXV. The transmission of the wireless telegram shall be preceded by the signal and terminated by the signal: — . — . — followed by the name of the sending station.

XXVI. When a wireless telegram to be transmitted contains more than 40 words, the sending station shall interrupt the transmission after each series of about 20 words by an interrogation point and shall not resume it until after it has obtained from the receiving station a repetition of the last word duly received, followed by an interrogation point: . . — — . .

In the case of transmission by series, acknowledgment of receipt shall be made after each wireless telegram.

XXVII. 1. When the signals become doubtful every possible means shall be resorted to finish the transmission. To this end the wireless telegram shall be repeated at the request of the receiving station, but not to exceed three times. If in spite of such triple repetition the signals are still unreadable the wireless telegram shall be canceled. If no acknowledgment of receipt is received the transmitting station shall again call up the receiving station. If no reply is made after three calls the transmission shall not be followed up any further.

2. If in the opinion of the receiving station the wireless telegram, although imperfectly received, is nevertheless capable of transmission, said station shall enter the words "reception doubtful" at the end of the preamble and let the wireless telegram follow.

XXVIII. All stations are bound to carry on the service with as little expense of energy as may be necessary to insure safe communication.

D. ACKNOWLEDGMENT OF RECEIPT AND CONCLUSION OF WORK

XXIX. 1. Receipt shall be acknowledged in the form prescribed by the International Telegraph Regulations, preceded by the call letters of the transmitting station and followed by those of the receiving station.

2. The conclusion of a correspondence between two stations shall be indicated by each station by means of the signal: . . . — . — followed by its call letters.

E. DIRECTIONS TO BE FOLLOWED IN SENDING WIRELESS TELEGRAMS

XXX. 1. In general, the shipboard stations shall transmit their wireless telegrams to the nearest coastal station.

2. A sender on board a vessel shall, however, have the right to designate the coastal station through which he desires to have his wireless telegram transmitted.

3. The station on shipboard shall then wait until such coastal station shall be the nearest. If this can not be done, the wishes of the sender are to be complied with only if the transmission can be effected without interfering with the service of other stations.

7. DELIVERY OF WIRELESS TELEGRAMS AT THEIR DESTINATION

XXXI. When for any cause whatever a wireless telegram proceeding from a vessel at sea can not be delivered to the addressee, a notice of non-delivery shall be issued. Such notice shall be transmitted to the vessel if possible. When a wireless telegram received by a shipboard station can not be delivered, the station shall notify the office of origin by official notice. Such notice shall be transmitted, whenever practicable, to the coastal station through which the wireless telegram has passed in transit; otherwise, to the nearest coastal station.

XXXII. If the ship for which a wireless telegram is intended has not signalled her presence to the coastal station within the period designated by the sender, or, in the absence of such designation, by the morning of the 29th day following, the coastal station shall notify the sender.

The latter shall have the right to ask, by a paid official notice, sent by either telegraph or mail and addressed to the coastal station, that his wireless telegram be held for a further period of 30 days for transmission to the vessel, and so on. In the absence of such request, the wireless telegram shall be put aside as not transmissible at the end of the 30th day (exclusive of the day of posting).

If, however, the coastal station has positive information that the vessel has left its radius of action before it has been able to transmit to her the wireless message, such station shall so notify the sender.

8. SPECIAL TELEGRAMS

XXXIII. The following telegrams shall not be accepted for transmission:

(a) Telegrams with answer prepaid;

(b) Money order telegrams;

(c) Telegrams calling for repetition of message (for purposes of verification);

(d) Telegrams calling for acknowledgment of receipt;

(e) Telegrams to be forwarded (if addressee is not found at the address given);

(f) Paid service telegrams, except in so far as transmission over the lines of the telegraph system is concerned;

(g) Urgent telegrams, except in so far as transmission over the lines of the telegraph system is concerned, subject to the application of the provisions of the International Telegraph Regulations;

(h) Telegrams to be delivered by express or mail.

9. FILES

XXIV. The originals of wireless telegrams and the documents relating thereto retained by the managements of the wireless telegraph service or by private enterprises shall be kept for a period of at least twelve months beginning with the month following that of the posting of the wireless telegram, with all the necessary precautions as regards secrecy.

Such originals and documents shall, as far as practicable, be sent at least once a month by the shipboard stations to the management of the wireless telegraph service to which they are subject.

10. REBATES AND REIMBURSEMENTS

XXXV. 1. With regard to rebates and reimbursements, the provisions of the International Regulations shall be applicable, taking into account the restrictions specified in Article XXXIII of the present Regulations and subject to the following reservations:

The time employed in the transmission of wireless telegrams and the time that wireless telegrams remain in a coastal station or station on shipboard shall not be counted as delays as regards rebates or reimbursements.

Reimbursements shall be borne by the different managements of the wireless telegraph service or private enterprises which have taken part in the transmission of the wireless telegram, each management or private enterprise relinquishing its share of the rate. Wireless telegrams to which articles 7 and 8 of the Convention of St. Petersburg are applicable shall remain subject, however, to the provisions of the International Telegraph Regulations, except when the acceptance of such telegrams of the result of an error made by the telegraph service.

2. When the acknowledgment of receipt of a wireless telegram has not reached the station which has transmitted the telegram, the charges shall be refunded only if the fact has been established that the wireless telegram is entitled to reimbursement.

11. ACCOUNTS AND PAYMENT OF CHARGES

XXXVI. 1. The coastal and shipboard charges shall not enter into the accounts provided for by the International Telegraph Regulations.

The accounts regarding such charges shall be liquidated by the managements of the wireless telegraph service of the countries concerned. They shall be drawn up by the wireless telegraph management to which the coastal stations are subject, and communicated by them to the wireless telegraph managements concerned.

2. For transmission over the lines of the telegraph system wireless telegrams shall be treated, so far as the payment of rates is concerned, in conformity with the International Telegraph Regulations.

3. For wireless telegrams proceeding from ships, the wireless telegraph management to which the shipboard station is subject shall be charged by the wireless telegraph management to which the coastal station is subject with the coastal and ordinary telegraph rates charged on board of vessels.

For wireless telegrams intended for ships, the wireless telegraph management which has collected the fees shall be charged directly by the wireless telegraph management to which the coastal station is subject with the coastal and shipboard rates. The latter shall credit the wireless telegraph management to which the vessel is subject with the shipboard rate.

In case the wireless telegraph management which has collected the charges is the same, however, as the one to which the shipboard station is subject, the shipboard rate shall not be charged by the wireless telegraph management to which the coastal station is subject.

4. The monthly accounts serving as a basis for the special accounts of wireless telegrams shall be made out for each telegram separately with all the necessary data within a period of six months from the month to which they refer.

5. The Governments reserve the right to enter into special agreements among themselves and with private enterprises (parties operating wireless telegraph stations, shipping companies, etc.) with a view of adopting other provisions with regard to accounts.

12. INTERNATIONAL BUREAU

XXXVII. The International Bureau of Telegraphs shall be entrusted with the duties specified in Article 13 of the Convention, subject to the consent of the Government of the Swiss Federation and the approval of the Telegraph Union.

The additional expenses resulting from the work of the International Bureau so far as wireless telegraphy is concerned shall not exceed 40,000 francs a year, exclusive of the special expenses arising from the convening of the International Conference.

These expenses shall form the subject of a special account, and provisions of the International Telegraph Regulations shall be applicable to them. Before the convening of the next Conference, however, each contracting Government shall notify the International Bureau of the class in which it desires to be entered.

XXXVIII. The management of the wireless telegraph service of the different countries shall forward to the International Bureau a table in conformity with the annexed blank, containing the data enumerated in said table for stations such as referred to in Article IV of the regulations. Changes occurring and additional data shall be forwarded by the wireless telegraph managements to the International Bureau between the 1st and 10th day of each month. With the aid of such data the International Bureau shall draw up a list which it shall keep up to date. The list and the supplements thereto shall be printed and distributed to the wireless telegraph managements of the countries concerned; they may also be sold to the public at the cost price.

The International Bureau shall see to it that the same call letters for several wireless telegraph stations shall not be adopted.

13. MISCELLANEOUS PROVISIONS.

XXXIX. The managements of the wireless telegraph service shall give to agencies of maritime information such data regarding losses and casualties at sea or other information of general interest to navigation, as the coastal stations may properly report.

XL. The exchange of correspondence between shipboard stations such as referred to in Article 1 of the Convention shall be carried on in such a manner as not to interfere with the service of the coastal stations, the latter, as a general rule, being accorded the right of priority for the public service.

XLI. 1. In the absence of special agreements between the parties concerned, the provisions of the present Regulations shall be applicable analogously to the exchange of wireless telegrams between two vessels at sea, subject to the following exceptions:

(a) To Article XIV. The shipboard rate falling to the transmitting ship shall be collected from the sender, and that falling to the receiving ship shall be collected from the addressee;

(b) To Article XVIII. The order of transmission shall be regulated in each case by mutual agreement between the corresponding stations.

(c) To Article XXXVI. The rates for the

wireless telegrams in question shall not enter into the accounts provided for in that article, such charges falling to the wireless telegraph managements which have collected them.

2. Retransmission of wireless telegrams exchanged between vessels at sea shall be subject to special agreement between the parties concerned.

XLII. The provisions of the International Telegraph Regulations shall be applicable analogously to wireless telegraph correspondence in so far as they are not contrary to the provisions of the present regulations.

In conformity with Article 11 of the Convention of Berlin, these Regulations shall go into effect on the first day of July, 1908.

In witness whereof the respective plenipotentiaries have signed one copy of the present Regulations, which shall be deposited in the archives of the Imperial Government of Germany, and a copy of which shall be transmitted to each of the Parties.

Done at Berlin, November 3, 1906.

For Germany:
KRAETKE.
SYDOW.

For United States:
CHARLEMAGNE TOWER.
H. N. MANNEY.
JAMES ALLEN.
JOHN I. WATERBURY.

For Argentina:
J. OLMI.

For Austria:
BARTH.
FRIES.

For Denmark:
N. R. MEYER.
I. A. VOEHITZ.

For Spain:
IGNACIO MURCIA.
RAMON ESTRADA.
RAFAEL RAVENA.
ISIDRO CALVO.
MANUEL NORIEGA.
ANTONIO PELAEZ-CAMPOMANES.

For Hungary:
PIERRE DE SZALAY.
DR. DE HENNYEY.
HOLLOS.

For Belgium:
F. DELARGE.
E. BUELS.

For Brazil:
CESAR DE CAMPOS.

For Bulgaria:
Iv. STOYANOVITCH

For Chile:
J. MUNOZ HURTADO.
J. MEYER.

For Monaco:
J. DEPELLEY

For Norway:
HEFTYE.
O. T. EIDEM.

For Netherlands:
KRUYT.
PERK.
HOVEN.

For France:
J. BORDELONGUE.
L. GASCHARD.
BOULANGER.
A. DEVOS.

For Great Britain:
H. BABINGTON SMITH
A. E. BETHELL.
R. L. HIPPISLEY.

For Greece:
T. ARGYROPOULOS.

For Italy:
J. COLOMBO.

For Japan:
OSUKE ASANO.
ROKURE YASHIRO.
SHUNKICHI KIMURA.
ZIRO TANAKA.
SABURO HYAKUTAKE

For Mexico:
JOSE M. PEREZ.

For Persia:
HOVHANNES KHAN.

For Portugal:
PAULO BENJAMIN CABRAL.

For Roumania:
GR. CERKEZ.

For Russia:
VICTOR BILIBINE.
A. REMMERT.
W. KEDRINE.

For Sweden:
HERMAN RYDIN
A. HAMILTON.

For Turkey:
NAZIF BEY.

For Uruguay:
F. A. COSTANZO.

EXTRA FROM THE INTERNATIONAL TELEGRAPH CONVENTION, SIGNED AT ST. PETERSBURG, JULY 10–22, 1875

(See Article 17 of the Convention)

ARTICLE 1

The High Contracting Parties concede to all persons the right to correspond by means of the international telegraphs.

ARTICLE 2

They bind themselves to take all the necessary measures for the purpose of insuring the secrecy of the correspondence and its safe transmission.

ARTICLE 3

They declare, nevertheless, that they accept no responsibility as regards the international telegraph service.

ARTICLE 5

TELEGRAMS ARE CLASSED IN THREE CATEGORIES:

1. State telegrams: those emanating from the Head of the Nation, the Ministers, the Commanders-in-Chief of the Army and Naval forces, and the Diplomatic or Consular Agents of the Contracting Governments, as well as the answers to such telegrams.

2. Service telegrams: those which emanate from the Managements of the Telegraph Service of the Contracting States and which relate either to the international telegraph service or to subjects of public interest determined jointly by such Managements.

3. Private telegrams.

In the transmission, the State telegrams shall have precedence over other telegrams.

ARTICLE 6

State telegrams and service telegrams may be issued in secret language, in any communications.

Private telegrams may be exchanged in secret language between two States which admit of this mode of correspondence.

The States which do not admit of private telegrams in secret language upon the expedition or arrival of the same, shall allow them to pass in transit, except in the case of suspension defined in article 8.

ARTICLE 7

The High Contracting Parties reserve the right to stop the transmission of any private telegram which may appear dangerous to the safety of the State, or which may be contrary to the laws of the country, to public order or good morals.

ARTICLE 8

Each Government also reserves the right to suspend the international telegraph service for an indefinite period, if deemed necessary by it, either generally, or only over certain lines and for certain classes of correspondence, of which such Government shall immediately notify all the other Contracting Governments.

ARTICLE 11

Telegrams relating to the international telegraph service of the Contracting States shall be transmitted free of charge over the entire systems of such States.

ARTICLE 12

The High Contracting Parties shall render accounts to one another of the charges collected by each of them.

ARTICLE 17

The High Contracting Parties reserve respectively the right to enter among themselves into special arrangements of any kind with regard to points of the service which do not interest the States generally.

Appendix G. Public 264—62d Congress, S. 6412
An Act To Regulate Radio Communications

Sec. 1. Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That a person, company, or corporation within the jurisdiction of the United States shall not use or operate any apparatus for radio communication as a means of commercial intercourse among the several States, or with foreign nations, or upon any vessel of the United States engaged in interstate or foreign commerce, or for the transmission of radiograms or signals the effect of which extends beyond the jurisdiction of the State or Territory in which the same are made, or where interference would be caused thereby with the receipt of messages or signals from beyond the jurisdiction of the said State or Territory, except under and in accordance with a license, revocable for cause, in that behalf granted by the Secretary of Commerce and Labor upon application therefor; but nothing in this Act shall be construed to apply to the transmission and exchange of radiograms or signals between points situated in the same State: Provided, That the effect thereof shall not extend beyond the jurisdiction of the said State or interfere with the reception of radiograms or signals from beyond said jurisdiction; and a license shall not be required for the transmission or exchange of radiograms or signals by or on behalf of the Government of the United States, but every Government station on land or sea shall have special call letters designated and published in the list of radio stations of the United States by the Department of Commerce and Labor. Any person, company, or corporation that shall use or operate any apparatus for radio communication in violation of this section, or knowingly aid or abet another person, company, or corporation in so doing, shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding five hundred dollars, and the apparatus or device so unlawfully used and operated may be adjudged forfeited to the United States.

Sec. 2. That every such license shall be in such form as the Secretary of Commerce and Labor shall determine and shall contain the restrictions, pursuant to this Act, on and subject to which the license is granted; that every such license shall be issued only to citizens of the United States or Porto Rico or to a company incorporated under the laws of some State or Territory or of the United States or Porto Rico, and shall specify the ownership and location of the station in which said apparatus shall be used and other particulars for its identification and to enable its range to be estimated; shall state the purpose of the station, and, in case of a station in actual operation at the date of passage of this Act, shall contain the statement that satisfactory proof has been furnished that it was actually operating on the above-mentioned date; shall state the wave length or the wave lengths authorized for use by the station for the prevention of interference and the hours for which the station is licensed for work; and shall not be construed to authorize the use of any apparatus for radio communication in any other station than that specified. Every such license shall be subject to the regulations contained herein, and such regulations as may be established from time to time by authority of this Act or subsequent Acts and treaties of the United States. Every such license shall provide that the President of the United States in time of war or public peril or disaster may cause the closing of any station for radio communication and the removal therefrom of all radio apparatus, or may authorize the use or control of any such station or apparatus by any department of the Government, upon just compensation to the owners.

Sec. 3. That every such apparatus shall at all times while in use and operation as aforesaid be in charge or under the supervision of a person or persons licensed for that purpose by the Secretary of Commerce and Labor. Every person so licensed who in the operation of any radio apparatus shall fail to observe and obey regulations contained in or made pursuant to this act or subsequent acts or treaties of the United States, or any one of them, or who shall fail to enforce obedience thereto by an unlicensed person while serving under his supervision, in addition to the punishments and penalties herein prescribed, may suffer the suspension of the said license for a period to be fixed by the Secretary of Commerce and Labor not exceeding one year. It shall be unlawful to employ any unlicensed person or for any unlicensed person to serve in charge or in supervision of the use and operation of such apparatus, and any person violating this provision shall be guilty of a misdemeanor, and on conviction thereof shall be punished by a fine of not more than one hundred dollars or imprisonment for not more than two months; or both, in the discretion of the court, for each and every such offense: Provided, That in case of emergency the Secretary of Commerce and Labor may authorize a collector of customs to issue a temporary permit, in lieu of a license, to the operator on a vessel subject to the radio ship act of June twenty-fourth, nineteen hundred and ten.

Sec. 4. That for the purpose of preventing or minimizing interference with communication between stations in which such apparatus is operated, to facilitate radio communication, and to further the prompt receipt of distress signals, said private and commercial stations shall be subject to the regulations of this section. These regulations shall be enforced by the Secretary of Commerce and Labor through the collectors of customs and other officers of the Government as other regulations herein provided for.

The Secretary of Commerce and Labor may, in his discretion, waive the provisions of any or all of these regulations when no interference of the character above mentioned can ensue.

The Secretary of Commerce and Labor may grant special temporary licenses to stations actually engaged in conducting experiments for the development of the science of radio communication, or the apparatus pertaining thereto, to carry on special tests, using any amount of power or any wave lengths, at such hours and under such conditions as will insure the least interference with the sending or receipt of commercial or Government radiograms, of distress signals and radiograms, or with the work of other stations.

In these regulations the naval and military stations shall be understood to be stations on land.

REGULATIONS

Normal Wave Length

First. Every station shall be required to designate a certain definite wave length as the normal sending and receiving wave length of the station. This wave length shall not exceed six hundred meters or it shall exceed one thousand six hundred meters. Every coastal station open to general public service shall at all times be ready to receive messages of such wave lengths as are required by the Berlin convention. Every ship station, except as hereinafter provided, and every coast station open to general public service shall be prepared to use two sending wave lengths, one of three hundred meters and one of six hundred meters, as required by the international convention in force: Provided, That the Secretary of Commerce and Labor may, in his discretion, change the limit of wave length reservation made by regulations first and second to accord with any international agreement to which the United States is a party.

Other Wave Lengths

Second. In addition to the normal sending wave length all stations, except as provided hereinafter in these regulations, may use other sending wave lengths: Provided, That they do not exceed six hundred meters or that they do exceed one thousand six hundred meters: Provided further, That the character of the waves emitted conforms to the requirements of regulations third and fourth following.

Use of a "Pure Wave"

Third. At all stations if the sending apparatus, to be referred to hereinafter as the "transmitter," is of such a character that the energy is radiated in two or more wave lengths, more or less sharply defined, as indicated by a sensitive wave meter, the energy in no one of the lesser waves shall exceed ten per centum of that in the greatest.

Use of a "Sharp Wave"

Fourth. At all stations the logarithmic decrement per complete oscillation in the wave trains emitted by the transmitter shall not exceed two-tenths, except when sending distress signals or signals and messages relating thereto.

Use of a "Standard Distress Wave"

Fifth. Every station on shipboard shall be prepared to send distress calls on the normal wave length designated by the international convention in force, except on vessels of small tonnage unable to have plants insuring that wave length.

Signal of Distress

Sixth. The distress call used shall be the international signal of distress: . . . — — — . . .

Use of "Broad Interfering Wave" for Distress Signals

Seventh. When sending distress signals, the transmitter of a station on shipboard may be tuned in such a manner as to create a maximum of interference with a maximum of radiation.

Distance Requirements for Distress Signals

Eighth. Every station on shipboard, whenever practicable, shall be prepared to send distress signals of the character specified in regulations fifth and sixth with sufficient power to enable them to be received by day over sea a distance of one hundred nautical miles by a shipboard station equipped with apparatus for both sending and receiving equal in all essential particulars to that of the station first mentioned.

"Right of Way" for Distress Signals

Ninth. All stations are required to give absolute priority to signals and radiograms relating to ships in distress; to cease all sending on hearing a distress signal; and, except when engaged in answering or aiding the ship in distress, to refrain from sending until all signals and radiograms relating thereto are completed.

Reduced Power for Ships Near a Government Station

Tenth. No station on shipboard, when within fifteen nautical miles of a naval or military station, shall use a transformer input exceeding one kilowatt, nor, when within five nautical miles of such a station, a transformer input exceeding one-half kilowatt, except for sending signals of distress, or signals or radiograms relating thereto.

Intercommunication

Eleventh. Each shore station open to general public service between the coast and vessels at sea shall be bound to exchange radiograms with any similar shore station and with any ship station without distinction of the radio system adopted by such stations, respectively, and each station on shipboard shall be bound to exchange radiograms with any other station on shipboard without distinction of the radio systems adopted by each station, respectively.

It shall be the duty of each such shore station, during the hours it is in operation, to listen in at intervals of not less than fifteen minutes and for a period not less than two minutes, with the receiver tuned to receive messages of three hundred-meter wave lengths.

Division of Time

Twelfth. At important seaports and at all other places where naval or military and private commercial shore stations operate in such close proximity that interference with the work of naval and military stations cannot be avoided by the enforcement of the regulations contained in the foregoing regulations concerning wave lengths and character of signals emitted, such private or commercial shore stations as do interfere with the reception of signals by the naval and military stations concerned shall not use their transmitters during the first fifteen minutes of each hour, local standard time. The Secretary of Commerce and Labor may, on the recommendation of the department concerned, designate the station or stations which may be required to observe this division of time.

Government Stations To Observe Division of Time

Thirteenth. The naval or military stations for which the above mentioned division of time may be established shall transmit signals or radiograms only during the first fifteen minutes of each hour local standard time, except in case of signals or radiograms relating to vessels in distress, as hereinbefore provided.

Use of Unnecessary Power

Fourteenth. In all circumstances, except in case of signals or radiograms relating to vessels in distress, all stations shall use the minimum amount of energy necessary to carry out any communication desired.

General Restrictions on Private Stations

Fifteenth. No private or commercial station not engaged in the transaction of bona fide commercial business by radio communication or in experimentation in connection with the development and manufacture of radio apparatus for commercial purposes shall use a transmitting wave length exceeding two hundred meters, or a transformer input exceeding one kilowatt, except by special authority of the Secretary of Commerce and Labor contained in the license of the station: Provided, That the owner or operator of a station of the character mentioned in this regulation shall not be liable for a violation of the requirements of the third or fourth regulations to the penalties of one hundred dollars or twenty-five dollars, respectively, provided in this section unless the person maintaining or operating such station shall have been notified in writing that the said transmitter has been found, upon tests conducted by the Government, to be so adjusted as to violate the said third and fourth regulations, and opportunity has been given to said owner or operator to adjust said transmitter in conformity with said regulations.

Special Restrictions in the Vicinities of Government Stations

Sixteenth. No station of the character mentioned in regulation fifteenth situated within five nautical miles of a naval or military station shall use a transmitting wave length exceeding two hundred meters or a transformer input exceeding one-half kilowatt.

Ship Stations To Communicate With Nearest Shore Stations

Seventeenth. In general, the shipboard stations shall transmit their radiograms to the nearest shore station. A sender on board a vessel shall, however, have the right to designate the shore station through which he desires to have his radiograms transmitted. If this can not be done, the wishes of the sender are to be complied with only if the transmission can be effected without interfering with the service of other stations.

Limitations for Future Installations in Vicinities of Government Stations

Eighteenth. No station on shore not in actual operation at the date of the passage of this act shall be licensed for the transaction of commercial business by radio communication within fifteen nautical miles of the following naval or military stations, to wit: Arlington, Virginia; Key West, Florida; San Juan, Porto Rico; North Head and Tatoosh Island, Washington; San Diego, California; and those established or which may be established in Alaska and in the Canal Zone; and the head of the department having control of such Government stations shall, so far as in consistent with the transaction of governmental business, arrange for the transmission and receipt of commercial radiograms under the provisions of the Berlin convention of nineteen hundred and six and future international conventions or treaties to which the United States may be a party, at each of the stations above referred to, and shall fix the rates therefor, subject to control of such rates by Congress. At such stations and wherever and whenever shore stations open for general public business between the coast and vessels at sea under the provisions of the Berlin convention of nineteen hundred and six and future international conventions and treaties to which the United States may be a party shall not be so established as to insure a constant service day and night without interruption, and in all localities whenever such services shall not be maintained by a commercial shore station within one hundred nautical miles of a naval radio station, the Secretary of the Navy shall, so far as in consistent with the transaction of Government business, open naval radio stations to the general public business described above, and shall fix rates for such service, subject to control of such rates by Congress. The receipts from such radiograms shall be covered into the Treasury as miscellaneous receipts.

Secrecy of Messages

Nineteenth. No person or persons engaged in or having knowledge of the operation of any station or stations shall divulge or publish the contents of any messages transmitted or received by such station, except to the person or persons to whom the same may be directed, or their authorized agent, or to another station employed to forward such message to its destination, unless legally required so to do by the court of competent jurisdiction or other competent authority. Any persons guilty of divulging or publishing any message, except as herein provided, shall, on conviction thereof be punishable by a fine of not more than two hundred and fifty dollars or imprisonment for a period of not exceeding three months, or both fine and imprisonment, in the discretion of the court.

Penalties

For violation of any of these regulations, subject to which a license under sections one and two of this act may be issued, the owner of the apparatus shall be liable to a penalty of one hundred dollars, which may be reduced or remitted by the Secretary of Commerce and Labor, and for repeated violations of any of such regulations the license may be revoked.

For violation of any of these regulations, except as provided in regulation nineteenth, subject to which a license under section three of this act may be issued, the operator shall be subject to a penalty of twenty-five dollars, which may be reduced or remitted by the Secretary of Commerce and Labor, and for repeated violations of any such regulations, the license shall be suspended or revoked.

Sec. 5. That every license granted under the provisions of this act for the operation or use of apprartus for radio communication shall prescribe that the operator thereof shall not willfully or maliciously interfere with any other radio communication. Such interference shall be deemed a misdemeanor, and upon conviction thereof the owner or operator, or both, shall be punishable by a fine of not to exceed five hundred dollars or imprisonment for not to exceed one year, or both.

Sec. 6. That the expression "radio communication" as used in this act means any system of electrical communication by telegraphy or telephony without the aid of any wire connecting the points from and at which the radiograms, signals, or other communications are sent or received.

Sec. 7. That a person, company, or corporation within the jurisdiction of the United States shall not knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent distress signal or call or false or fraudulent signal, call, or other radiogram of any kind. The penalty for so uttering or transmitting a false or fraudulent distress signal or call shall be a fine of not more than two thousand five hundred dollars or imprisonment for not more than five years, or both, in the discretion of the court, for each and every such offense, and the penalty for so uttering or transmitting, or causing to be uttered or transmitted, any other false or fraudulent signal, call, or other radiogram shall be a fine of not more than one thousand dollars or imprisonment for not more than two years, or both, in the discretion of the court, for each and every such offense.

Sec. 8. That a person, company, or corporation shall not use or operate any apparatus for radio communication on a foreign ship in territorial waters of the United States otherwise than in accordance with the provisions of sections four and seven of this act and so much of section five as imposes a penalty for interference. Save as aforesaid, nothing in this act shall apply to apparatus for radio communication on any foreign ship.

Sec. 9. That the trial of any offense under this act shall be in the district in which is committed, or if the offense is committed upon the high seas or out of the jurisdiction of any particular State or district the trial shall be in the district where the offender may be found or into which he shall be first brought.

Sec. 10. That this act shall not apply to the Philippine Islands.

Sec. 11. That this act shall take effect and be in force on and after four months from its passage.

Approved, August 13, 1912.

Appendix H. The U. S. Navy Standard Drawing Number System

This was a part of a general coordination system drawn up by the Navy in 1914–15. In this system, drawings, reports, photographs, lists, specifications, etc., were filed according to origin, class, size, serial number, and alteration.

All of these characteristics were expressed in the identifying number which appeared in the lower right-hand corner of the sheet, be it drawing, typed statement, photo, etc. Typical of this would be a drawing numbered "RW 46A 114 B." Analyzing this:

1. "R" identified the drawing as being of the radio classification.
2. "W" indicated that yard which originated the drawing -- in this case, the Washington Navy Yard.
3. "46" was the class applying to the subject treated. In the example, the drawing is of a radio receiver, to which class 46 has been assigned.
4. "A" indicated the size of the sheet. There were four sizes. Size A, as here used, was identical with the Navy typewriter paper size -- 8"x10½", slightly smaller than commercial 8½"x11" size.
5. "114" was the serial number. This meant that this drawing was No. 114 in Class 46 as prepared by Washington Yard. The preceding numbers from No. 1 on might have been all reports, or all photos, or—as probable—a mixture; as long as they referred to receivers, they received the "next serial number" in their turn.
6. "B" was the alteration letter. It meant that there had been an original drawing with the same serial number but no final letter; the first alteration received the letter "A," and this present alteration, the second, received the letter "B."

Generalities of the system:

a. The letters assigned to the various Navy Yards were:

B Boston
Y New York
L Philadelphia
E Bureau of Engineering
W Washington Navy Yard
N Norfolk Yard
C Charleston Yard
M Mare Island Yard
S Puget Sound

b. The classes ran from 1 upward. Only a few of the major ones were:

2 Semimonthly reports
13 Specifications
31 Transmitter condensers
46 Receiver systems
66 Antennas

c. The sizes adopted as standard drawings were:

8"x10½" indicated by letter "A"
8"x21" indicated by letters "AA"
16"x21" indicated by letter "F"
misc. other sizes indicated by letter "Z"

d. Photographs were all of "A" size, but were identified by the letter "P."

e. Reports, and papers not requiring a larger space, essentially were all of "A" size.

f. In filing drawings at each yard, the files were arranged:

First, by yards, alphabetically.
Next, under each yard, by classes.
Next, under each class, by serial number.
Last, under each serial number, by alteration letter.

Appendix I. The U.S. Navy Type Number System

In 1916 the Navy adopted a Type Number System to identify radio equipment by the designing agency's assigned designation as listed below:

CA	American Radio Research Corp.
CB	Crocker Wheeler Co.
CD	Dubilier Condenser Co.
CE	E. J. Simon
CF	de Forest Radio Telephone & Telegraph Co.
CG	General Electric Co.
CH	Electrose Insulator Co.
CK	Kilbourne and Clark
CL	Fritz Lowenstein
CM	Marconi Wireless Telegraph Co. of America
CN	National Electric Supply Co.
CO	Copely Manufacturing Co.
CP	Cutting and Washington
CQ	International Radio Telegraph Co.
CR	Wireless Specialty Apparatus Co.
CS	Sperry Manufacturing Co.
CT	Federal Telegraph Co.
CU	Miller Resse Hutchinson
CV	Weston Instrument Co.
CW	Western Electric Co.
CY	Wireless Improvement Co.
CAB	Baldwin Telephone Co.
CAC	Central Telephone Co.
CAD	Domestic Manufacturing Engineering Co.
CAE	Cutler Hammer Manufacturing Co.
CAF	John Firth
CAG	General Radio Co.
CAH	Cutter Manufacturing Co.
CAJ	Holtzer Manufacturing Co.
CAK	William J. Murdock
CAL	Locke Insulator Co.
CAM	Manhattan Electrical Supply Co.
CAN	Sagame Electric Co.
CAD	Ward Leonard Co.
CAP	Frank B. Perry
CAQ	Robbins and Meyers
CAR	Roller Smith
CAS	Chloride of Silver Co.
CAT	American Transformer Co.
CAU	Triumph Electric Co.
CAW	C. & C. Electric Co.
CAX	Metropolitan Electric Co.
CAV	Industrial Controller Co.
CAY	West Electric Controller Co.
SE	Bureau of Engineering

Appendix J. Radio Patents Owned by or Licensed to the United States Government, 1923

Patent No.	*Date of issue*	*Inventor*	*Title*
736483	18 Aug. 1903	G. F. R. Blockmann	Telegraphic transmitting and receiving apparatus.
743056	3 Nov. 1903	F. Braun	Wireless telegraphy.
744897	24 Nov. 1903	F. Braun	Means for directing electric waves for use in wireless telegraphy.
750429	26 Jan. 1904	F. Braun	Wireless electric transmission of signals over surfaces.
763164	21 June 1904	J. Donitz	Apparatus for determining the length of waves and observing the oscillations in electric oscillation systems.
763345	21 June 1904	F. Braun	Means for tuning and adjusting electric circuits.
776337	29 Nov. 1904	Mandelstam and Brandee.	Wireless signaling system.
776380	29 Nov. 1904	F. Braun	Method of producing quick electrical oscillations of different phases.
776216	13 Dec. 1904	S. Musits	Apparatus for wireless telephone.
783923	28 Feb. 1905	A. Blondel	Wireless telegraphy by electric waves.
783992	28 Feb. 1905	A. Blondel	Wireless telegraphy by electric waves.
789449	9 May 1905	V. Poulsen	Method of producing alternating currents with a high number of vibrations.
790179	16 May 1905	F. Braun	Wireless telegraphy.
790250	16 May 1905	Braun and Randahl	Apparatus for increasing the discharge energy of electrical vibration systems.
793609	27 June 1905	V. Poulsen	Apparatus for alternating current.
797169	15 Aug. 1905	F. Braun	Space telegraphy.
797544	15 Aug. 1905	F. Braun	Space telegraphy.
810150	16 Jan. 1906	C. Hulsmeyer	Wireless transmitting and receiving mechanism for electric waves.
813914	27 Feb. 1906	R. H. Randahl	Wireless electric signaling system.
820169	8 May 1906	G. Von Arco	Resonance circuit.
820258	8 May 1906	R. H. Randahl	Detector for electromagnetic waves or the like.
824682	26 June 1906	A. Blondel	Method of practicing wireless telegraphy.
828864	14 Aug. 1906	W. Schloemilch	Receiver for wireless telegraphy.
835023	6 Nov. 1906	H. Heinicke	Transformer.
839029	18 Dec. 1906	V. Poulsen	Receiving system for wireless transmission of signals.
851336	23 Apr. 1907	G. Von Arco	Transmitter for wireless telegraphy.
858668	2 July 1907	P. O. Pederson	Receiver for electrical oscillations.
883437	31 Mar. 1908	L. D. Wildman	Receiver for space signaling systems.
890451	9 June 1908	V. Poulsen	Generator of electric oscillations.
892311	30 June 1908	O. Scheller	Apparatus for plotting resonance curves.
892312	30 June 1908	O. Scheller	System for receiving undamped electric oscillations.
897779	1 Sept. 1908	V. Poulsen	Receiver for wireless signaling.
905537	1 Dec. 1908	G. Jahr	Receiver arrangement for wireless telegraphy.
914483	9 Mar. 1909	Erdman and Fischer	Device for preventing collisions at sea.
929487	27 July 1909	V. Poulsen	Wireless signaling system.
930588	10 Aug. 1909	Wirth and Beck	Receiving electrical system.
936258	5 Oct. 1909	W. Schloemilch	Receiver for space telegraphy.

Patent No.	Date of issue	Inventor	Title
958181	17 May 1910	W. Schloemilch	Receiver for wireless telegraphy.
958209	17 May 1910	G. Von Arco	Portable station for wireless telegraphy.
959100	24 May 1910	G. Von Arco	Aerial conductor arrangement for wireless telegraphy.
961645	14 June 1910	V. Poulsen	Receiver for wireless transmission of signals.
962262	29 June 1910	Schloemilch and Pichon.	Wave detector for wireless telegraphy.
966705	9 Aug. 1910	V. Poulsen	Signaling by wireless telegraphy.
970850	20 Sept. 1910	A. Plizener	Wireless telephony.
986405	7 Mar. 1911	P. O. Pederson	Transmitting apparatus for wireless telegraphy.
994426	6 June 1911	R. H. Randahl	Receiver for wireless telegraphy.
1003210	12 Sept. 1911	Schloemilch and Pichon.	Wave detector for wireless telegraphy.
1003374	12 Sept. 1911	Schloemilch and Pichon.	Wave detector for wireless telegraphy.
1005471	10 Oct. 1911	R. H. Randahl	Antenna.
1012496	19 Dec. 1911	G. Wirth	Wireless receiving electric system.
1014722	16 Jan. 1912	R. H. Randahl	Means for varying the period of oscillation of two oscillatory circuits.
1029573	11 June 1912	Wirth, Beck and Knauss.	Wireless controlled current distributor.
1043117	5 Nov. 1912	E. Von Lepel	Apparatus for producing rapid electric oscillations.
1051744	28 Jan. 1913	A. Meissner	Spark gap for impulse excitation.
1052849	11 Feb. 1913	Schloemilch and Pichon.	System of radiotelephony.
1059391	22 Apr. 1913	V. Poulsen	Receiver for wireless transmission of signals.
1061717	13 May 1913	G. Von Arco	Arrangement for producing electrical oscillations.
1064325	10 June 1913	B. Hirsch	Wave meter.
1067851	22 July 1913	A. Wasmus	Means for producing Rontgen rays.
1077733	4 Nov. 1913	A. Meissner	Means for producing slightly damped oscillations by shock excitation.
1082221	23 Dec. 1913	G. Von Arco	Radiotelegraphic station.
1087126	17 Feb. 1914	Macku, Mandelstam and Papalexi.	Arrangement for producing slightly damped electrical oscillations.
1087549	17 Feb. 1914	V. Poulsen	Receiver for wireless transmission signals.
1087892	17 Feb. 1914	Schloemilch and Von Sronk.	Means for receiving electrical oscillations.
1091159	24 Mar. 1914	P. O. Pederson	Transmitting apparatus for electric signaling.
1092294	7 Apr. 1914	J. Schiessler	Receiving apparatus for alternative wireless telegraphy and telephony.
1099998	16 June 1914	J. Schiessler	Submarine signaling apparatus.
1101148	23 June 1914	J. Schiessler	Apparatus for the production and strengthening of electrical vibrations.
1103822	14 July 1914	W. Otts	High-tension oscillator.
1104556	21 July 1914	C. Schon	Photographic recording apparatus.
1116130	3 Nov. 1914	J. Schiessler	Electric capacitative inductive coupling.
1116059	3 Nov. 1914	W. Hahnemann	Antenna structure on aeroplanes for wireless signaling.
1131187	9 Mar. 1915	Von Arco and Randahl.	Self-inductive means for electrical oscillatory circuits.
1135604	13 Apr. 1915	A. Meissner	Process and apparatus for determining the position of radio telegraphic receivers.
1142625	8 June 1915	E. Reitz	Discharge tube.
1148279	27 June 1915	Von Arco and Randahl.	Self-inductive means for electrical oscillatory circuits.
1148827	3 Aug. 1915	W. Burstyn	Wireless telephone transmitter.
1150395	17 Aug. 1915	C. Schon	Telegraphic transmission.
1151824	31 Aug. 1915	G. Reuthe	Electric condenser.
1152272	31 Aug. 1915	H. Boss	Electric spark gap.
1158309	26 Oct. 1915	C. Schon	Transmitter for wireless telegraphy.
1161142	23 Nov. 1915	C. V. Logwood	Wireless communication.

Patent No.	*Date of issue*	*Inventor*	*Title*
1162830	7 Dec. 1915	Von Arco and Meissner.	System for signaling by wireless telegraphy under the quenched-spark method.
1163180	7 Dec. 1915	Schloemilch and Lieb.	Means for strengthening weak electric impulses.
1168837	18 Jan. 1916	E. Von Lepel	Method of producing electrical oscillations.
1169082	18 Jan. 1916	Von Lieben, Leisz and Strauss.	Discharge-tube.
1169676	25 Jan. 1916	Pichon and Meissner.	Frequency-converter.
1170552	8 Feb. 1916	A. Meissner	Means for producing alternating current by cathode-ray tubes.
1175472	14 Mar. 1916	R. H. Randahl	Coupling for electrical oscillation circuits.
1175489	14 Mar. 1916	Von Arco and Randahl.	Self-inductive means for electrical oscillatory circuit.
1178890	11 Apr. 1916	Von Arco, Leib and Frey.	Radiotelegraphy station.
1179353		L. F. Fuller	Wireless telegraphy.
1180075	18 Apr. 1916	P. F. Pichon	Production and detection of electric oscillations.
1181556	2 May 1916	Von Arco and Meissner.	Means for producing high-frequency currents.
1186654	13 June 1916	A. Franke	Means for producing phase-shifted oscillations in a plurality of independent oscillation circuits.
1190165	4 July 1916	Hahnemann	Submarine telegraphy or telephony.
1197366	5 Sept. 1916	Hahnemann	Wireless signaling apparatus.
1204720	14 Nov. 1916	E. Von Lepel	Circuit arrangement for wireless transmitters.
1210540	2 Jan. 1917	Rukep and Schloemilch.	Cathode-ray tube.
1214214	30 Jan. 1917	Roulsen and Pederson.	Generator of high-frequency current.
1214283	30 Jan. 1917	L. DeForest	Wireless telegraphy.
1214591	6 Feb. 1917	G. Reuthe	Antenna for radiotelegraph station.
1214621	6 Feb. 1917	Von Arco and Meissner	Means for producing electrical oscillations with the aid of an auxiliary oscillation circuit.
1216538	20 Feb. 1917	Von Arco and Randahl	Means for producing electrical oscillations.
1216615	20 Feb. 1917	G. Seibt	Apparatus for producing powerful electrical oscillations.
1219550	20 Mar. 1917	Hahnemann	Antenna structure on airplanes for wireless signaling.
1224048	24 Apr. 1917	E. Von Lepel	Method of producing electrical oscillations of high frequency from direct current.
1224343	1 May 1917	J. O. Watkins	Wireless telegraphy.
1229740	12 June 1917	R. Rurstenan	Measuring instrument for Roentgen rays.
1231528	26 June 1917	P. O. Pederson	Generator for high-frequency currents.
1267018	21 May 1918	Von Arco and Meissner	Transmitting apparatus for wireless telegraphy and telephony.
1294177	11 Feb. 1919	W. Schloemilch	Wave detector.
1294983	18 Feb. 1919	Von Arco and Meissner	Station for wireless telegraphy and telephony.
1298490	25 Mar. 1919	L. F. Fuller	Electrical oscillation generator.
1300156	8 Apr. 1919	L. F. Fuller	Radiotelegraphy.
1300157	8 Apr. 1919	L. F. Fuller	Radiotelegraphy.
1306223	10 June 1919	L. F. Fuller	Radiotelegraphy.
1308530	1 July 1919	Reuthe	Controlling wireless telegraph transmitters.
1309283	8 July 1919	L. F. Fuller	Radiotelegraphy.
1311654	29 July 1919		Radio method and apparatus.
1314095	26 Aug. 1919	G. Reuthe	Antenna arrangement for wireless signaling and the like.
1314102	26 Aug. 1919	Von Arco and Meissner	Connection for electric relays working with ionized gas gap.
1316172	16 Sept. 1919	Marx and Fuller	Radiotelegraphy.
1320585	4 Nov. 1919	R. R. Beal	Wireless telegraphy.
1330254	10 Feb. 1920	L. F. Fuller	Radiotelegraphy.
1336833	13 Apr. 1920	L. F. Fuller	Radiotelegraphy.

1339191	4 May 1920	L. F. Fuller	Radiotelegraphy.
1344052	22 June 1920	Marx and Fuller	Radiotelegraphy.
1350695	24 Aug. 1920		Radio transmission system.
1352059	7 Sept. 1920		Wiggling electrode division of 1298.
1352883	14 Sept. 1920		Ignition key signaling.
1352886	14 Sept. 1920		Loop transmission.
1358143	9 Nov. 1920		Coupled compensation isolated loop.
1358144	9 Nov. 1920		Arcs in multiple.
1381626	14 June 1921		Impulse transformer system.
1385121	19 July 1921		Bullet nosed anode.
1394560	23 Mar. 1921		Method of and apparatus for transmitting radio energy.
1399945	13 Dec. 1921		Overlapping loops.
1410730	28 Mar. 1922		Hinged top generator.
1424141	25 July 1922		Condenser.
1447165	27 Feb. 1923		Directional finding, uni-directional reception and transmission.
1454307	8 May 1923		Single wave signaling.
1454624	8 May 1923		Radio signaling group frequency.
1454629	8 May 1923		Single wave coupled compensation.
1454630	8 May 1923		Single wave phase angle of residual current.
1454652	8 May 1923		Radio frequency transmission system.

(Report of the Federal Trade Commission on the Radio Industry, 1 December, 1923, Government Printing Office, 1924, Washington, D. C., Appendix, Exhibit A–3, pp. 114-116.

Appendix K. The U.S. Naval Communications Frequency Plan, 1926

In making the assignments in the U.S. Naval Communications Frequency Plan, 1926, paramount consideration was given to the communication requirements of the U.S. Fleet. Other primary considerations were the peacetime requirements of commercial radio activities; the requirements of international radio conventions; the requirements of other U.S. Government departments; and the necessity for radio intercommunication with the U.S. Army and merchant marine.

In assigning the channels, it was decided that insofar as possible a separation of 10 percent would be used on all frequencies assigned naval high-power stations and those assigned the low-powered ones using frequencies between 75 and 600 kc. For the low-powered stations using frequencies between 600 and 2000 kc. the channels were to be separated by 20 kc. and for those above 2000 kc., by 30 kc.

Frequency channels to fleet units were to be assigned so as to fall between limits of transmitters and receivers. It was noted that radio installations on ships and aircraft were such as to permit comparatively free assignment of ships to task groups composed of various types of ships.

Fleet, shore and naval district forces communications were to be kept in separate bands. Intercommunication was to be provided through one or more frequencies common to all systems.

Strategical, tactical and fire-control communications of the fleet were to be kept in different bands.

No frequencies were to be assigned the naval communication system which were in harmonic relation to one another—except above 4000 kc.

Above 4000 kc. four widely separated working frequencies, in harmonic relationship, were to be assigned each ship or station utilizing frequencies in that portion of the spectrum. This was to permit communication at all times of day or year in any direction and at the same time was an economical utilization of the ether spectrum.

The assignment of frequencies which were in "beat" relation to one another was avoided.

In applying the above frequency principles and considerations, frequencies ending in the numeral 5 were assigned the channels above 150 kc. Below 150 kc. fleet frequencies ended in 5 but those ashore ended in even numbers with the exception of zero which was not used unless absolutely required. This permitted the widest separation of the most harmful harmonic interferences in the high-frequency bands, avoided the difficulties in "beating" between the fleet and ashore, and at the same time permitted a more liberal distribution of channels of communication.

In the following table these principles were adhered to wherever practicable. Certain exceptions were made where international, national and certain technical considerations could not be overlooked.

Where the word "Fleet" is used, it was expected that the Commander in Chief, would assign the frequency to the individual units of the fleet concerned. This permitted flexibility in the assignment of channels of communication to task groups, the composition and nature of which change from time to time according to circumstances.

DETAILED NAVAL FREQUENCY ALLOCATION FOR PEACE AND WAR

High Power Shore Stations

*Peace allocation kilocycles***	*Use*	*War allocation kilocycles***
17.5	Annapolis	17.5
19.8	Cavite	19.8
26.1	Pearl Harbor	26.1
28.5	San Francisco No. 1	28.5
30.6	San Diego	30.6
32.8	Guam	32.8

*Peace allocation kilocycles***	*Use*	*War allocation kilocycles***
33.8	Puget Sound, San Juan	33.8
36.0	Washington	36.0
38.0	Heeia	38.0
42.8	San Francisco No. 2	42.8
46.0	Darien	46.0
48.0	Cordova	48.0
	Medium Power Shore Stations	
50.4	Guam, Washington (NAA)	50.4
52.0	St. Paul, Key West	52.0
54.0	Heeia	54.0
56.0	Norfolk, Puget Sound, Cavite	56.0
58.0	San Diego, Port Au Prince, Bar Harbor	58.0
60.0	North Head, Brownsville	60.0
62.0	San Francisco No. 1, San Juan	62.0
64.0	Charleston, Great Lakes	64.0
66.0	Peking, Tutuila, Guantanamo, San Francisco No. 2	66.0
68.0	Washington (NAL)	68.0
	Fleet	
75.0	Battleship Division No. 3	75.0
85.0	Battleship Division No. 2	85.0
95.0	Battleship Division No. 4	95.0
	Fleet And Low Power Shore Stations	
100.0	Annapolis	100.0
102.0	Boston, Key West, San Diego	102.0
104.0	Norfolk No. 1, Virginia Beach, Sitka, Eureka, Darien No. 1	104.0
106.0	Philadelphia-Portsmouth, Cordova, Pearl Harbor No. 1, San Juan-New Orleans	106.0
108.0	New York, Charleston, San Francisco	108.0
112.0	Washington NAA, Washington NAL, Pensacola, North Head, Cape Mala, Kodiak-Heeia, Cavite-Pearl Harbor No. 2	112.0
115.0	Battleship Division No. 5	115.0
118.0	Newport, Cape Hatteras, Annapolis, NAK, Guantanamo, Darien No. 2, Bar Harbor, St. Paul, Puget Sound, Hilo	118.0
—	Shore stations taken over in war	122.0
125.0	Battleship Division No. 1	125.0
	Low Power Shore Stations	
128.0 Φ	La Palma, St. Augustine, Puerto Obaldia, Seward	128.0
132.0 Φ	Great Lakes, Norfolk No. 2, Savannah, Jupiter, Brownsville, St. Thomas, Port Au Prince, Colon, Dutch Harbor, Tutuila. Olongapo, Guam, Peking	132.0
—	Shore stations taken over in war	134.0
—	Shore stations taken over in war	136.0
—	Shore stations taken over in war	138.0
—	Shore stations taken over in war	142.0
—	Shore stations taken over in war	144.0
—	Shore stations taken over in war	146.0
—	Shore stations taken over in war	148.0
	Fleet (Major Task Force) And Navigational Aids	
155.0	Fleet	155.0
175.0	Fleet	175.0

*Peace allocation kilocycles***	*Use*	*War allocation kilocycles***
195.0	Fleet	195.0
215.0	Fleet	215.0
245.0	Fleet	245.0
275.0	Fleet	275.0
—	Radio Beacons	300.0
315.0	CINC U.S. Fleet, Navy calling	315.0
375.0	Radio compass stations,%% Radio Compass Communication	375.0
—	Fleet	405.0
445.0	Fleet and New London	445.0
500.0	Distress commercial calling	500.0
550.0	Aircraft squadrons and shore stations for aircraft	555.0
—	Fleet	565.0
	NAVAL TRANSPORTATION SERVICE—FLEET	
605.0#	Naval district patrol planes*; Air stations%%%	605.0
615.0#	Naval transportation service* and Fleet	615.0
635.0#	Naval district forces (vessels and section base stations)*	635.0
655.0#	Naval transportation service* and Fleet	655.0
685.0#	Naval district patrol planes* and air stations, OFU, St. Croix, TAU	685.0
705.0#	Naval transportation service* and Fleet	705.0
715.0#	Naval district forces (vessels and section base stations)	715.0
725.0#	Naval transportation service and Fleet*	725.0
755.0#	Naval district patrol planes and air stations*	755.0
785.0#	Naval transportation service and Fleet*	785.0
815.0#	Naval district forces (vessels and section base stations)*	815.0
835.0#	Naval transportation service and Fleet*	835.0
845.0#	Naval district patrol planes and air stations*	845.0
865.0#	Naval transportation service and Fleet-St. John*	865.0
885.0#	Naval district forces (vessels and section base stations)*	885.0
905.0#	Naval transportation service and Fleet*	905.0
925.0#	Naval district patrol planes and air stations*	925.0
955.0#	Naval transportation service and Fleet*	955.0
965.0#	Naval district forces (vessels and section base stations)*	965.0
985.0#	Naval district patrol planes and air stations*	985.0
995.0#	Naval transportation service and Fleet	995.0
	DISTRICT AIRCRAFT	
1105.0#	Naval district forces (vessels and section base stations)*	1005.0
1015.0#	Fleet†	1015.0
1025.0#	Naval district forces%%%	1025.0
1055.0#	Fleet†	1055.0
1095.0#	Fleet†	1095.0
1115.0#	Naval district forces	1115.0
1135.0#	Fleet†	1135.0
1145.0#	Naval district forces	1145.0
1155.0#	Naval district forces	1155.0
1165.0#	Fleet†	1165.0
1175.0#	Naval district forces	1175.0
1185.0#	Naval district forces	1185.0
1195.0#	Fleet†	1195.0
1245.0#	Naval district forces	1245.0
1255.0#	Naval district forces	1255.0
1285.0#	Fleet	1285.0
1295.0#	Naval district forces	1295.0
	NAVAL DISTRICT FORCES	
1305.0#	Fleet	1305.0
1315.0#	Naval district forces	1315.0
1325.0#	Fleet	1325.0

Peace allocation kilocycles**	Use	War allocation kilocycles**
1455.0 #	Fleet	1455.0
1465.0 #	Naval district forces	1465.0
1475.0 #	Fleet	1475.0
1485.0 #	Naval district forces	1485.0
—	Fleet	1515.0
—	Naval district forces	1525.0
—	Fleet	1535.0
—	Naval district forces	1545.0
—	Fleet	1555.0
—	Naval district forces	1565.0
—	Fleet	1585.0
—	Naval district forces	1595.0
—	Fleet	1605.0
—	Naval district forces	1635.0
—	Fleet	1645.0
—	Fleet	1655.0
—	Naval district forces	1675.0
—	Fleet	1685.0
—	Naval district forces	1735.0
—	Fleet	1745.0
—	Naval district forces	1765.0
—	Fleet	1775.0
—	Naval district forces	1795.0
—	Fleet	1825.0
—	Naval district forces	1835.0
—	Fleet	1855.0
—	Naval district forces	1865.0
—	Fleet	1885.0
—	Fleet	1895.0
—	Naval district forces	1915.0
—	Fleet	1945.0
—	Naval district forces	1955.0
—	Fleet	1975.0
—	Naval district forces	1985.0

Fleet, (Intra Unit Tactical)

—	Fleet	2005.0
—	Fleet	2035.0
—	Fleet	2065.0
—	Fleet	2095.0
—	Fleet	2135.0
—	Fleet	2165.0
—	Fleet	2195.0
—	Fleet	2235.0
—	Fleet	2265.0
2305.0	Fleet and Fleet base shore stations***	2305.0
2335.0	Fleet	2335.0
2385.0	Fleet	2385.0
2405.0	Fleet	2405.0
2435.0	Fleet	2435.0
2485.0	Fleet	2485.0
2515.0	Fleet	2515.0
2545.0	Fleet	2545.0
2575.0	Fleet	2575.0
2605.0	Fleet	2605.0
2655.0	Fleet	2655.0
2685.0	Fleet	2685.0
2715.0	Fleet	2715.0
2745.0	Fleet	2745.0

*Peace allocation kilocycles***	*Use*	*War allocation kilocycles***
—	Fleet	2785.0
—	Fleet	2815.0
—	Fleet	2845.0
2885.0	Fleet	2885.0
2915.0	Fleet	2915.0
2955.0	Fleet	2955.0
2995.0	Fleet	2995.0

FLEET (FIGHTING PLANES, TORPEDO AND BOMBING PLANES)

3005.0	Fleet and naval shore stations for aircraft%	3005.0
3035.0	Fleet	3035.0
3065.0	Fleet	3065.0
3095.0	Fleet	3095.0
3155.0	Fleet	3155.0
3195.0	Fleet	3195.0

FLEET (OBSERVATION PLANES AND AIRCRAFT FIRE OBSERVATION COMMUNICATION)

3235.0	Fleet	3235.0
3265.0	Fleet	3265.0
3295.0	Fleet	3295.0
3345.0	Fleet	3345.0
3385.0	Fleet	3385.0
3415.0	Fleet	3415.0
3445.0	Fleet	3445.0
3475.0	Fleet and naval shore stations% and for aircraft	3475.0
3505.0 # #	Fleet	3505.0
3535.0 # #	Fleet	3535.0
3585.0 # #	Fleet	3585.0
3615.0 # #	Fleet	3615.0
3665.0 # #	Fleet	3665.0
3695.0 # #	Fleet	3695.0
3725.0 # #	Fleet	3725.0
3755.0 # #	Fleet	3755.0
3785.0 # #	Fleet	3785.0
3815.0 # #	Fleet	3815.0
3845.0 # #	Fleet	3845.0
3865.0 # #	Fleet	3865.0
3905.0 # #	Fleet	3905.0
3935.0 # #	Fleet	3935.0
3965.0 # #	Fleet	3965.0
3985.0 # #	Fleet	3985.0

FLEET AND SHORE HIGH FREQUENCY

4015.0, 8030.0, 12,045.0, 16,060.0	Washington No. 1, Pearl Harbor No. 1	4015.0, 8030.0, 12,045.0, 16,060.0
4035.0, 8070.0, 12,105.0, 16,140.0	San Francisco No. 1, Cavite No. 1	4035.0, 8070.0, 12,105.0, 16,140.0
4045.0, 8090.0, 12,135.0, 16,160.0	Darien No. 1, Guam No. 1, Tutuila No. 1	4045.0, 8090.0, 12,135.0, 16,180.0
4055.0, 8110.0, 12,165.0, 16,220.0	Puget Sound, Norfolk	4055.0, 8110.0, 12,165.0, 16,220.0
4065.0, 8130.0, 12,195.0, 16,260.0	Brownsville	4065.0, 8130.0, 12,195.0, 16,260.0
4075.0, 8150.0, 12,225.0, 16,300.0	Pearl Harbor No. 2	4075.0, 8150.0, 12,225.0, 16,300.0
4105.0, 8210.0, 12,315.0, 16,420.0	Fleet (cruisers)	4105.0, 8210.0, 12,315.0, 16,420.0
4115.0, 8230.0, 12,345.0, 16,460.0	Cordova, New York	4115.0, 8230.0, 12,345.0, 16,460.0
4135.0, 8270.0, 12,405.0, 16,540.0	Darien No. 2	4135.0, 8270.0, 12,405.0, 16,540.0
4145.0, 8290.0, 12,435.0, 16,580.0	Boston	4145.0, 8290.0, 12,435.0, 16,580.0
4155.0, 8310.0, 12,465.0, 16,620.0	Pensacola, Lakehurst	4155.0, 8310.0, 12,465.0, 16,620.0
4175.0, 8350.0, 12,525.0, 16,700.0	San Francisco No. 2	4175.0, 8350.0, 12,525.0, 16,700.0
4195.0, 8390.0, 12,585.0, 16,780.0	Bar Harbor	4195.0, 8390.0, 12,585.0, 16,780.0
4205.0, 8410.0, 12,615.0, 16,820.0	Fleet (Fleet and Cruiser Submarines and Scouting Aircraft	4204.0, 8410.0, 12,615.0, 16,820.0

*Peace allocation kilocycles***	*Use*	*War allocation kilocycles***
4215.0, 8430.0, 12,645.0, 16,860.0	Cavite No. 2	4215.0, 8430.0, 12,645.0, 16,860.0
4225.0, 8450.0, 12,675.0, 16,900.0	St. Paul	4225.0, 8450.0, 12,675.0, 16,900.0
4235.0, 8470.0, 12,705.0, 16,940.0	Tutuila No. 2	4235.0, 8470.0, 12,705.0, 16,940.0
4245.0, 8490.0, 12,735.0, 16,980.0	San Diego	4245.0, 8490.0, 12,735.0, 16,980.0
4265.0, 8530.0, 12,795.0, 17,060.0	Guam No. 2	4265.0, 8530.0, 12,795.0, 17,060.0
4295.0, 8590.0, 12,885.0, 17,180.0	Washington No. 2	4295.0, 8590.0, 12,885.0, 17,180.0
4305.0, 8610.0, 12,915.0, 17,220.0	Anacostia	4305.0, 8610.0, 12,915.0, 17,220.0
4315.0, 8630.0, 12,945.0, 17,260.0	Great Lakes	4315.0, 8630.0, 12,945.0, 17,260.0
4325.0, 8650.0, 12,975.0, 17,300.0	New Orleans	4325.0, 8650.0, 12,975.0, 17,300.0
4345.0, 8690.0, 13,035.0, 17,380.0	Philadelphia	4345.0, 8690.0, 13,035.0, 17,380.0
4355.0, 8710.0, 13,065.0, 17,420.0	Peking, Key West	4355.0, 8710.0, 13,085.0, 17,420.0
4385.0, 8770.0, 13,155.0, 17,540.0	Fleet (flagships)	4385.0, 8770.0, 13,155.0, 17,540.0
4405.0, 8810.0, 13,215.0, 17,620.0	Charleston	4405.0, 8810.0, 13,215.0, 17,620.0
4435.0, 8870.0, 13,305.0, 17,740.0	Quantico, Port Au Prince	4435.0, 8870.0, 12,305.0, 17,740.0
4475.0, 8950.0, 13,425.0, 17,900.0	Guantanamo	4475.0, 8950.0, 13,425.0, 17,900.0
4525.0, 9050.0, 13,575.0, 18,100.0	San Juan	4575.0, 9050.0, 13,575.0, 18,100.0

Notes

ΦΦ The frequencies marked ΦΦ are used primarily for non-Government marine traffic.

** These allocations are not exclusive for the Navy, in many cases they are shared with the Army, especially where there would be no interference.

* Naval observation aircraft attached to the fleet will use frequencies marked * if 3000 to 4000 kc., proves unsuccessful.

† Naval fighting planes etc. will use frequencies marked † if 3000 to 3200 kc. proves unsuccessful.

‡ The use of frequencies marked ‡ is restricted in peace as follows: The officer in charge of military or naval radio operations will confer with the Department of Commerce supervisor of radio in the locality, where interference is probable, to determine the frequencies which may be used with the least interference. Naval and military operations will then be confined so far as is possible to the time periods, frequencies, and powers which will cause minimum interference in the locality. It is understood that military and naval operation in this band will in general be limited to an antennae radiation of 75-meter amperes, to daylight hours, and to a limited number of hours per week and weeks per year. The amount of operation will differ somewhat in different parts of the country.

‡‡ The use of frequencies marked ‡‡ is limited in peace to communications between naval aircraft and naval vessels working aircraft.

‡‡‡ Navy Radio Washington is assigned a broadcast frequency of 690 kc.

% The naval radio shore stations assigned for communication with aircraft on 550, 3005, and 3475 kc. in peace are: Lakehurst, Pensacola, Anacostia, Boston, Bar Harbor, New York, Norfolk, Quantico, Balboa, Colon, Puget Sound, San Francisco, San Diego, Hilo, Pearl Harbor, Philadelphia, Dahlgren, Cavite, Guam, Guantanamo, Jupiter, Key West, New Orleans, Eureka, and St. Augustine. Whenever the Navy desires to use the frequencies 550, 3005, 3475 k.c., or any of them, at naval shore stations designated to communicate with aircraft, it will notify the Interdepartmental Radio Advisory Committee of the location of such station or stations.

%% The following naval radio stations use 375 kc. to transmit radio compass bearings: Bar Harbor, Cape Elizabeth, Maine, Boston, North Truro, Mass., Surfside, Mass., Prices Neck, R.I., Amagansett, Long Island, Fire Island, N.Y., Lakehurst, N.J., Cape Henlopen, Del., Virginia Beach, Va., Cape Hatteras, N.C., Morehead City, N.C., North Island, S.C., Folly Island, S.C., Savannah, Ga., Types Island, Ga., Jupiter, Fla., Key West, Fla., Pensacola, Fla., South Pass, La., Galveston, Texas, St. Paul, Alaska, Cape Hinchinbrook, Alaska, Soapstone Point, Alaska, Cattle Point, Wash., Smith Island, Wash., New Dungeness, Wash., Tatoosh, Wash., Destruction Island, Wash., Klipsan Beach, Wash., Fort Stevens, Oreg., Marshfield, Oreg., Empire, Oreg., Point St. George, Calif., Eureka, Calif., Point Reyes, Calif., Point Montara, Calif., Farallon Island, Calif., Point Arguello, Calif., Point Hueneme, Calif., Point Fermin, Calif., San Diego, Calif., Whitefish Point, Mich., Detour Point, Mich., Eagle Harbor, Mich., Colon, C.Z., Cape Mala, C.Z., Thatchers Island, Mass., Deer Island, Mass., Fourth Cliff, Mass., Sandy Hook, N.J., Manasquan, N.J., Cape May, N.J., Bethany Beach, Del., Hog Island, Va., Poyners Hill, N.C., Cape Lookout, N.C., Imperial Beach, Calif., Grand Marias, Mich.

*** The Fleet base stations are: Newport, New York, Norfolk, Guantanamo, Puget Sound, San Francisco, San Diego, Balboa, Pearl Harbor, Cavite.

%%% The actual assignment of frequencies to "naval district forces" and to "naval district patrol planes and air stations" in war will be made by the Chief of Naval Operations in cooperation with the War Department.

There are some experimental naval radio stations which use miscellaneous frequencies from time to time—these are: Bellevue (NKF), Annapolis (NZP), Dahlgren (NDY), Indian Head (NBG), San Diego (NPL.) and Paris Island (NAV).

Appendix L. U.S. Naval Radio Stations, 1921-25

(R., receiving; TH., High-powered Transmitter; TL., Low-powered Transmitter; TM., Medium-powered Transmitter; DF., Direction Finder Station.)

First Naval District

Bar Harbor, Maine (R–DF).
Sea Wall, Maine (TM).
Portsmouth, N.H. (TL–R).
Portland, Maine (TL–R).
Cape Elizabeth, Maine (DF).
Chatham, Mass. (TL–R).
Thatcher's Island, Mass. (DF), established 15 September 1924.
Gloucester, Mass. (DF), disestablished 15 September 1924.
Deer Island, Mass. (DF).
Fourth Cliff, Mass. (DF).
Surfside, Mass. (DF).
North Truro, Mass. (DF).
Price's Neck, R.I. (DF).
Melville, R.I. (TL), disestablished July 1924.
Coasters Harbor Is., R. I. (R), (TL) July 1924.
Boston, Mass. (TL), (R) 1925.
Chelsea, Mass. (R), disestablished 1925.

Third Naval District

Brooklyn, N.Y. (TL–R).
Sandy Hook, N.Y. (DF).
Fire Island, N.Y. (DF).
Manasquan, N.Y. (DF).
Sayville, N.Y. (TH).
Buffalo, N.Y. (TL–R), transferred to Army 1 July 1923.
Amagansett, N.Y. (TL–R–DF), disestablished 1 October 1922.

Fourth Naval District

Philadelphia, Pa. (TL–R).
Cape May, N.J. (TL–R–DF), disestablished 14 May 1923.
Bethany Beach, Del. (DF).
Cape Henlopen, Del. (DF).
Lakehurst, N.J. (DF-Aircraft only).

Fifth Naval District

Hampton Roads, Va. (R).
Virginia Beach, Va. (DF).
Hog Island, Va. (DF).
Portsmouth, Va. (TM).
Baltimore, Md. (TL–R), disestablished 1 March 1923.
Morehead City, N.C. (TL–R).
Cape Hatteras, N.C. (TL–R–DF).
Poyner's Hill, N.C. (DF).
Cape Lookout, N.C. (DF).

Sixth Naval District

Charleston, S.C. (TM–R).
Savannah, Ga. (TL–R).
Folly Island, S.C. (DF).
North Island, S.C. (DF).

Seventh Naval District

Key West, Fla. (TM–R–DF), (DF) established 1 February 1925.
Jupiter, Fla. (TL–R–DF).
St. Augustine, Fla. (TL–R), 0800–2300 commencing 4 May 1923.

Eighth Naval District

Pensacola, Fla. (TL–R–DF)
New Orleans, La. (TM–R).
Mobile, Ala. (TL–R).
Pass a Loutre, La. (DF), disestablished 1923.
Grand Island, La. (DF), disestablished 1923.
Burrwood, La. (DF), disestablished 1923.
Sabine Pass, La. (DF).
Port Eads, South Pass, La. (DF), established 1923.
Port Arthur, Tex. (TL–R), disestablished 9 June 1923.
Galveston, Tex. (TL–R–DF), disestablished 1 February 1925.
Point Isabel, Tex. (TL–R), disestablished 24 August 1923.
Brownsville, Tex. (TL–R), established 24 August 1923.

Ninth Naval District

Great Lakes, Ill. (TM–R).
Chicago, Ill. (TL–R).
Milwaukee, Wis. (TL–R).
Manistique, Mich. (TL–R), disestablished 22 October 1923.
Eagle Harbor, Mich. (TL–R–DF).

Duluth, Minn. (TL–R).
White Fish Point, Wis. (TL–R–DF).
Detour Point, Wis. (TL–R–DF).
Mackinac Is., Mich. (TL–R), disestablished 2 October 1923.
Grand Marias, Mich. (DF).
Alpena, Mich. (DF).
Detroit, Mich. (TL–R), disestablished 22 October 1923.
Cleveland, Ohio (TL–R), loaned to Post Office Department 31 July 1923.

ELEVENTH NAVAL DISTRICT

Chollas Heights, Calif. (TH).
North Island, Calif. (R).
Point Loma, Calif. (DF), closed 1925.
Imperial Beach, Calif. (DF).
Point Firmin, Calif. (DF).
San Pedro, Calif. (R), (TL) 6 September 1924.
Inglewood, Calif. (TL), disestablished September 1924.
Point Hueneme, Calif. (TL R–DF).

TWELFTH NAVAL DISTRICT

San Francisco, Calif. (TH).
Mare Island, Calif. (TH).
Yerba Buena, Calif. (R).
Eureka, Calif. (TL–R–DF).
Point Arguello, Calif. (TL–R–DF).
Farallon Islands, Calif. (DF).
Point Montara, Calif. (DF).
Point Reyes, Calif. (DF).
Point St. George, Calif. (DF), established 1925.

THIRTEENTH NAVAL DISTRICT

Marshfield, Oreg. (TL–R), disestablished 15 November 1925.
Northhead, Wash. (TL–R).
Astoria, Wash. (TL–R).
Seattle, Wash. (TL–R), disestablished 1 July 1923.
Keyport, Wash. (TL).
Puget Sound, Wash. (R), (TM) 1 July 1923.
Tatoosh, Wash. (TL–R–DF).
Fort Stevens, Oreg. (DF).
Klipsan Beach, Oreg. (DF), established 4 August 1923.
New Dungeness, Wash. (DF).
Cattle Point, Wash. (DF).
Smith Island, Wash. (DF), established 4 August 1923.
Destruction Island, Wash. (DF), established 10 February 1925.
Sitka, Alaska (TL–R).
Ketchikan, Alaska (TL–R), transferred to Army 4 September 1924.
Juneau, Alaska (TL–R), transferred to Army 29 August 1924.
Hanscom, Alaska (TM), transferred to Army 1925.
Eyak, Alaska (R).
Seward, Alaska (TL—R).
Soapstone Point, Alaska (TL—R—DF).
Hichenbrook, Alaska (TL–R), (DF) established 1 September 1923.
Kodiak, Alaska (TL–R).
Dutch Harbor, Alaska (TL–R).
St. George, Pribiloffs (TL–R), transferred to Bureau of Fisheries 1 September 1924.
St. Paul, Pribiloffs (TM–R–DF).

FOURTEENTH NAVAL DISTRICT

Pearl Harbor, Hawaii (TH).
Heeia, Hawaii (TH).
Wailupe, Hawaii (R).
Hilo, Hawaii (TL–R), established August 1924.

FIFTEENTH NAVAL DISTRICT

Darien, C. Z. (TH).
Balboa, C. Z. (R).
Coco Solo, C. Z. (TL–R), disestablished 12 February 1923.
Colon, C. Z. (DF), established 18 May 1925.
Cape Mala, C. Z. (TL–R), (DF) established 4 August 1925.
Puerto Obaldia, R. P. (TL–R).
La Palma, R. P. (TL–R)
Managua, Nicaragua (TL–R), disestablished 1925.
Toro Point, C. Z. (TL–R), established 1925.

NAVY DEPARTMENT

Annapolis, Md. (TH).
Naval Academy, Annapolis, Md. (TL–R).
Arlington, Va. (TM).
Navy Yard, Washington, D.C. (TL).
Quantico, Va. (TL–R).
Indian Head, Md. (TL–R).
Navy Department, Washington, D.C. (R).
Bar Harbor, Maine (Monitor), ceased being monitor for Navy Department receiving 2 July 1923.
Sayville, N. Y. (Keying), in reserve, 1925.

CARRIBEAN AREA

Cayey, P. R. (TH).
San Juan, P. R. (R).
Guantanamo Bay, Cuba (TM–R).
Navassa Island (TL–R), transferred to Bureau of Lighthouses 1925.
Port Au Prince, Haiti (TL–R).
St. Thomas, V. I. (TL–R).
St. Croix, V. I. (TL–R).
San Domingo, S. D. (TL–R), transferred to Dominican Government 16 September 1925.

WESTERN PACIFIC AREA

Tutuila, Samoa (TM–R).
Ofu, Samoa (TL–R).
Guam, M.I. (TH–R)
Cavite, P.I. (TH)
Los Banoa, P.I. (R)
Olongapo, P.I. (TL–R)
Vladivostok, S. (TL–R)
Shanghia, China (R)
Peking, China (TM–R).

Appendix M. U.S. Naval Radio Equipment

TRANSMITTERS

Spark Transmitters

The Navy list of type numbers assigned radio apparatus issued in September 1923 (RE 15A 105B) contains numerous types of spark transmitters. This was resultant of the wartime contracts with various manufacturers who provided equipments built to Navy specifications but which varied in construction and therefore had non-interchangeable components. Following the end of the war efforts were made to standardize installations and the following 500-cycle quenched gap spark transmitters were in general use on types of ships as indicated:

Power (kw.)	*Type number*	*Frequency range (kc.)*	*Number of frequencies*	*Type of ship*
	SE 3531	1,700–2,400		Auxiliary set for naval vessels
	SE 3612*	1,700–2,400		Do.
½	CM 296	1,700–2,400		Auxiliary for ships fitted with 2 and 5 kw. arc transmitters
½	SE 606	500–1,000	2	Shipping Board
½	CE 606A	500–705	2	Do.
½	CE 859	315–1,000	6	Submarines and tugs
½	CR 654A	315–1,000	6	Do.
½	CE 827	315–1,000	6	Do.
1	CE 861	315–1,000	6	Mine sweepers
1	SE 1060	500–1,000	3	Shipping Board
1	SE 1075	315–1,000	6	Submarine chasers
1	CE 1221	315–1,000	6	Do.
2	CM 306		8	Air Stations
2	CM 305	150–1,000	8	Naval Vessels
2	CL 342	150–1,000	8	Do.
2	CL 344	150–1,000	8	Do.
2	CL 345	150–1,000	8	Do.
2	CR 655	150–1,000	8	Do.
2	CM 1080	500–1,000	3	Shipping Board
2	SE 1205	500–1,000	3	Do.
2	CM 307	150–1,000	8	Battleships (secondary), destroyers, tenders and auxiliaries
5	CR 1125	95–1,000	9	Do.
5	CM 858	95–1,000	9	Do.
5	SE 1210	95–1,000	9	Do.
5	SE 1211	95–1,000	9	Do.
10	CL 343	95–400	8	Battleships
10	CL 304	95–400	8	Do.

*Same as SE 3531 except for voltage applied motor generator.

All 2, 5 and 10 kw. spark transmitters on combatant ships were equipped with the model BC motor buzzer components which could be substituted for the gaps by a simple switching arrangement. This motor buzzer set consisted of a constant-speed motor-driven brass wheel, with its periphery divided by 10 equally spaced insulating segments, in contact with a brush. The wheel performed the functions of interrupting the direct current and forming the spark gap. It provided less radiation and interference, and with its normal transmitting range of 50 miles, was used for intrafleet communications. The model BD motor buzzer transmitter was developed to provide similar equipment on combatant ships not fitted with 2, 5, or 10 kw. spark sets. Later these were replaced by the auxiliary spark transmitters SE 3531 and 3612 which were developed to provide intrafleet communications in the frequency band 1700–2400 kc. in order to permit simultaneous transmission and reception of intrafleet and long-distance messages.

Arc Transmitters

The arc transmitters used by the Navy were developed by the Federal Telegraph Company and were based upon the early Poulsen patents. At the time the Navy became interested in the arc as a transmitter the Federal Telegraph Company had developed and built them in sizes up to 30 kw. During the war, with Navy support and guidance, they were able to successively develop them in power ratings of 100, 200, 350, 500 and 1,000 kw. These equipments were reliable and simple of operation. Until 1922 their emissions were mushy and consisted of two separate waves and the harmonics thereof at which time the undersired emissions were eliminated by the installation of a uni-wave key and a current transforming circuit. The following arc transmitters were used by the Navy:

Power (kw.)	*Type Number*	*Arc voltage*	*Use*	*Signalling method*
2	K	350	Naval ships	Chopper, back shunt
2	Q	500	Merchant ships	Do.
2	X	500	Naval ships	Chopper, ignition key
5		500	Naval ships	Do.
20	CT 1038	500	Do.	Uniwave key
30	CT 1042	500	Do.	Do.
20	CT 1201	500	Do.	Do.
100		500	Shore stations	Do.
200		500	Do.	Do.
500		500	Do.	Do.

The basic components of the arc transmitter consisted of the following:

A source of direct current of suitable voltage.
An arc converter.
An antenna loading inductance (Helix.) and frequency changer.
An antenna and ground system.
A signalling device.
Ancilliary and control devices.

The direct current was provided by conventional motor-generator with the necessary control to supply direct current at the required voltage.

The arc converter consisted of a water-cooled bronze chamber in which the arc burned in hydrogen gas between a carbon electrode and a water-cooled copper one. Above and below this chamber there were two series field coils surrounding and energizing the two poles of the magnetic circuit. These poles projected into the chamber, one on each side of the arc to provide a magnetic blow-out which blew the arc flame to one side.

The frequency of the emitted signal was controlled by varying the antenna loading inductance by a frequency changing component.

The lower power arcs were equipped with a chopper which interrupted the energy delivered to the antenna and caused the radiation of interrupted continuous waves which permitted reception by stations equipped with damped wave receivers.

One of the undesirable features of the arc transmitter was the emission of signals at two differing frequencies. This condition was caused by the compensation method of keying wherein the transmitting key controlled a specific amount of antenna inductance by direct shortening of one or more turns of the antenna loading coil. This resulted in the radiation of one frequency with the key closed and another when open. This was eliminated by the development of the uniwave key by Lt. W. A. Eaton, USN.

The relay key was actuated by two solenoids which were controlled by a double relay which in turn was controlled by an ordinary Morse key. It consisted of eight pairs of contacts with one contact of each pair stationery. Four pairs were used for making and breaking the absorbing circuit and four pairs for making and breaking the antenna circuit. Each pair of contacts was bridged by a noninductive resistance and the four contacts of each of the two groups were connected in series. When the antenna circuit contacts were open four of the resistance units were in series with the antenna and when the absorbing circuit was open four of these units were in series with the absorbing circuit. The generated energy was dissipated by the absorbing circuit during open key periods.

The other undesirable feature, that of the radiated harmonics and the mushy sound of the signal was eliminated by the addition of a current-transforming circuit devised by Radio Aid W. A. Hallborg.

The Alexanderson Alternator

In 1915 Mr. E. F. W. Alexanderson of the General Electric Co. was successful in developing in alternator which generated continuous waves at very low frequency. This development was based upon earlier ideas of Dr. Reginald Fessenden. It consisted of a two-phase alternating current induction motor driving a high-speed generator through a gear system which increased the speed of the generator. The

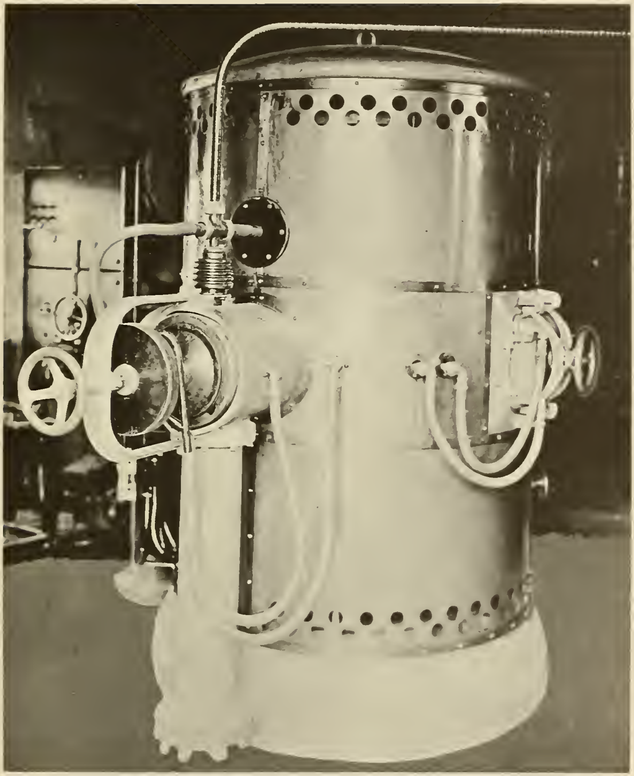


FIGURE M–1. 100 KW Federal Telegraph Company arc transmitter

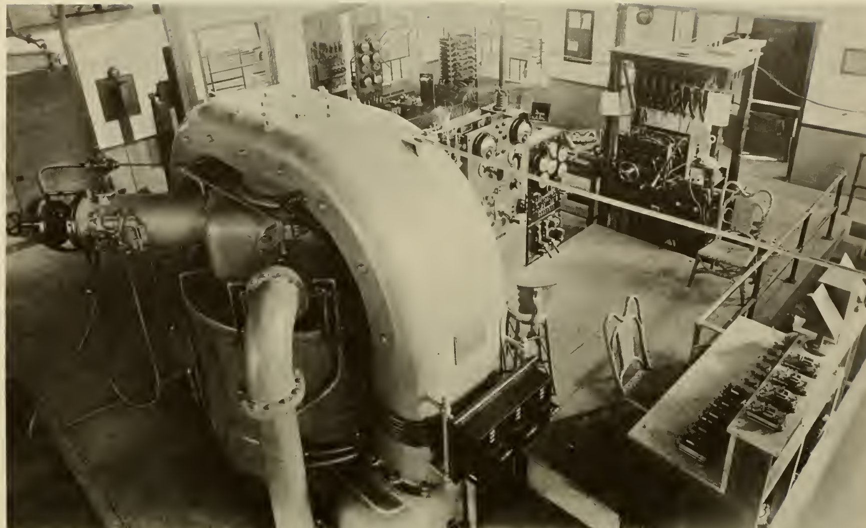


FIGURE M-2. 350 KW Federal Telegraph Company arc transmitter, 1919.

rotor of this generator was of steel and contained a number of slots on its periphery which were set up which induced alternating currents in the 64 armature coils wound in slots in the stator. These coils were coupled to a common secondary which in turn was directly connected to the antenna and ground systems. One of the stator coils was connected to an independent circuit through a mercury vapor rectifier and the current induced in it was used for operating the speed regulator. Accurate speed regulation was obtained through the use of choke coils which changed the voltage supply of the induction motor and thereby its speed. Since the radiated frequency is a function of alternator speed any desired frequency of 25 kc. or less could be obtained.

Keying was accomplished by opening a low, direct current powered magnetic amplifying circuit inductively coupled to the secondary which when closed threw the system out of resonance.

The antenna used with the alternator was also developed by Alexanderson and was multiple tuned by a number of spaced down leads each connected to its own loading coil and ground system, thereby greatly increasing the antenna efficiency.

Vacuum Tube Transmitters

The early vacuum tube or electronic transmitters were designed for any one or all of the following types of emission:

Continuous wave

Interrupted continuous wave (modulation of continuous wave of an audio frequency).

Telephony (modulation of continuous waves by voice).

The first satisfactory vacuum tube transmitter used in the Navy was the Western Electric Co. CW 938, a component of the CW 936 short range radio telephone equipment.

Following the war other vacuum tube sets were developed but none of the early ones were entirely satisfactory. In 1922, in an effort to eliminate the broad band spark alternating current vacuum tube sets were designed by Navy personnel utilizing the power and tuning components of spark transmitters.

The following is a list of electronic transmitters installed in ships and naval short stations during the period 1917–25.

Power (watts)	*Type Number*	*Frequency (kc.)*	*Emission*	*Use*
5	CW 938 [2]	870–1270	Voice modulation [1]	General.
5	TA	1500–2310	CW	Intrafleet.
5	TB [2]	610, 728, 822, 864 and 1027.	Voice modulation	Fire control.
150	TC	588, 592, 630, 708 and 741.	CW, kw, voice modulation	Battleships for aircraft spotting.
1,500	TD	109, 167, 308, 333, 375, 500 and 592.	do.	Airstations.
300	TE	with antenna 308, 375, 444, 500 and 592. with loop 308 and 444.	do.	Submarines.
300	TF	210, 250, 288, 308, 444, 500 and 592.	do.	Scout cruisers, Submarines and aircraft tenders.
300	TG	308, 375, 444, 500 and 592.	do.	Eagle boats.
6,000	TL [3]	200–600		Battleships.
100	TM [3]			Submarines.
6,000	TN [3]		CW	Shore stations.
100	TO [3]	500–1500	CW, Voice modulation	Battleships.

Notes. Models TH, TJ and TK were not placed under production. The designation TI was not used.

[1] The CW 938 was later modified to include 1 CW emission.

[2] These equipments were transceivers.

[3] These transmitters were originally spark transmitters modified into alternating current tube transformers.

The model TA transmitter was of Navy design. Only a few were constructed at the Washington Navy Yard.

Models TC, TD, TE, TF and TG were basically designed by the General Electric Co. but most of these equipments utilized the Navy designed antenna break relay.

Since all of these transmitters were basically of the same design the model TC is described. This transmitter was provided with the three normal types of emission and was designed basically for communications between battleships and their aircraft. Its reliable ranges were 50 miles for CW, 10 miles for 1 CW and 5 miles for telephony. It utilized six 75-watt vacuum tubes, three as oscillators, two as modulators and one as an audio amplifier. The antenna coupling inductance and variometer formed the secondary and the plate and grid inductances formed the secondary.

The transmitter was arranged to emit on either low, medium and high power. The constants of the antenna circuit determined the frequency. The controls of the transmitter were located on the front of the panel and included a frequency-changing switch, a signal switch, the power switch and the antenna variometer.

RECEIVING EQUIPMENT

Receiving equipment during the period 1912–25 included all apparatus between the receiving antenna switch and the ground connection and normally consisted of the following separately packaged units: receivers, audio and radio-auditio-frequency amplifiers, vacuum tube detectors, radiofrequency drivers and wavemeters. Some installations were equipped with acceptor-rejector circuits or other means of increasing selectivity.

Unlike later-day practice receivers of this period normally consisted of the antenna or primary circuit used for tuning the antenna to resonance with the frequency of the signal to be received, the secondary circuit, tuned to resonance with the primary thus transferring the maximum amount of current to the detector circuit. Some of these earlier receivers contained a simple crystal or other nonvacuum tube detector. The normal practice in using vacuum tube detectors and amplifiers was to connect these units to the receiver by external binding posts.

In later units, the detecting and amplifying units were packaged together.

Receivers

Receivers normally used by naval ship and shore stations (excluding direction finder stations) during the period 1912–1928 included the following:

Type number (Model)	*Frequency (kc.)*	*Use*
IP 76		General utility
A	60–600	Do.
B	30–300	Do.
C	1,200–3,000	Landing force
SE 95	30–300	General utility
SE 143	100–1,200	Do.
CN 208	100–1,200	Do.
CN 240	30–300	Do.
CM 294	96–1,500	Do.
SE 889	30–300	Do.
SE 952	50–600	Do.
SE 1220	43–1,000	Do.
CW 1313	610, 728, 822, 864, 1027	Battleships, fire control
CG 1323	308, 375, 444, 500, 592	Battleships, aircraft spotting
SE 1420	43–1,200	General utility
SE 1530	10–50	Shore stations
SE 1899	12–300	General utility
SE 3649	12–375	Battleships
RA	16–1200	Submarines
RB	10–50	Shore stations
RC		Shore stations
RD	12–1200	Destroyers
RE	10–100	General service
RF	75–1,000	General service
RG	1,000–20,000	General service
RH	200–650	General service
RI	40–1,200	General service
RK	12–375	General service
RO	15-1,000/300-620/1,000-22,000	"S" Class submarines
RQ	15–1,000/1,000–22,000	Minesweepers
RS	3,750–22,000	Shore stations
RT	1,000–30,000	General service
RU	250–1,800	Fighting planes
RAA	10–1,000	AC superheterodyne—General service
RAB	1,0000–30,000	General service—AC superheterodyne
RAC	12–80	Shore stations

Acceptor-Rejector Circuit

The acceptor-rejector circuit, obtained from the Royal Navy, was used for two purposes: first, to reject undesired signals when using a broadly tuned receiver, and secondly, to make it possible to use a single antenna for dual reception of to distinctly separate frequencies.

For the first purpose the following circuit was used:

The inductance L was adjusted in such a manner that the resultant inductance and capacity of this portion of the circuit was exactly in resonance with the incoming signal with the nodal point exactly at the antenna connection to the Condenser C. When this condition obtains there is zero potential between the plates of this condenser. When the acceptor circuit, which was the primary of the receiver, was adjusted to the desired frequency incoming signals of that frequency set-up oscillations in that circuit. Undesired signals flowed through the untuned rejector to ground.

For the second purpose two acceptor-rejector circuits were used in parallel as shown below:
Two different nodal points were electrically established. In order to obtain these an additional circuit tuned to the first desired frequency was inserted in series with the antenna circuit and the acceptor-rejector circuit for the first desired frequency. This produced a nodal point in the first acceptor-rejector circuit at exactly the same point as before. By adjusting the variable inductance L′ the nodal point for the second acceptor-rejector circuit was established at the same relative position in the second acceptor-rejector circuit. Both acceptor circuits were then tuned to the specific frequency desired for each and then coupled to their receivers.

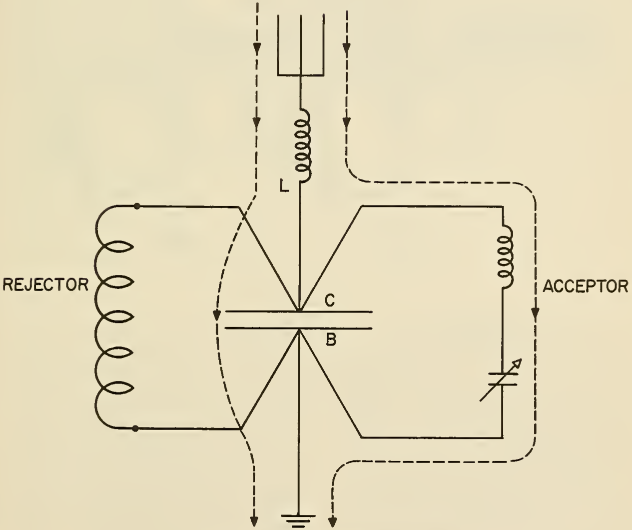


Figure M–3. Acceptor-rejector circuit.

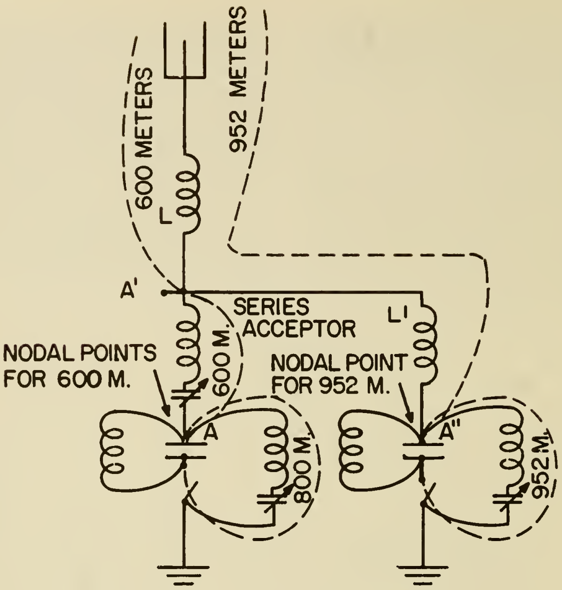


FIGURE M-4. Two acceptor-rejector circuits.

BALANCED COLLECTOR SYSTEMS

In the endeavor to reduce the static encountered in the reception of long-distance point-to-point circuits the Navy experimented with several forms of balanced antenna systems. Basically all these systems utilized diametrically opposing antennas erected on a line of bearing with the station to be received. Various combinations of loop and long straight wire antennas, the latter being either elevated, buried or submerged in fresh or salt water, were used. The basic principle of all these systems was the reduction of static by the out of phase relationship between the two opposing portions of the systems thereby balancing out a considerable portion of the static emanating from directions differing from that of the desired signals.

The Rogers Underground Collector System

The simplest of these various balanced systems was that of Mr. J. H. Rogers who perfected the first successful underground systems for the reception of long-distance radio signals. The penetration of the earth by a radio wave is a function of its frequency and the signal strengths as received on an underground collector are stronger at lower frequencies. For example, with the same antenna radiation the received signal strength at 50 kc. is 12 times that of a signal emitted at 500 kc. Further benefit is obtained by use of the underground collector because static generated by local atmospheric disturbances does not penetrate the earths surface to any appreciable extent. The schematic diagram of the Rogers' system is shown in Figure M-5.

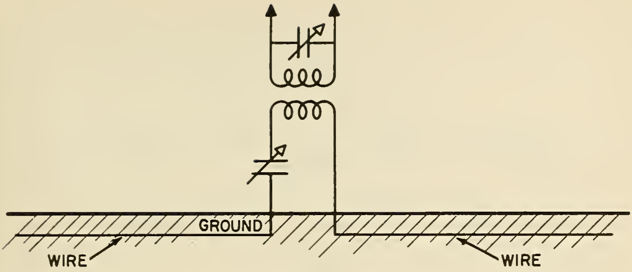


Figure M–5.

The Taylor Balance System

The Taylor balance system consisted of a grounded loop with inductance and variable capacitance and resistance in series balanced against an underground wire which was connected to the other side of the resistance. At this same connection a variable resistance was connected to ground to form a path for shunting static. The primary inductance of the receiving circuit was variably connected to the first-mentioned resistance through variable capacitance and grounded. The schematic diagram of this system, which was used at Belmar, N.J. and Chatham, Mass., during World War I is shown in Figure M–6.

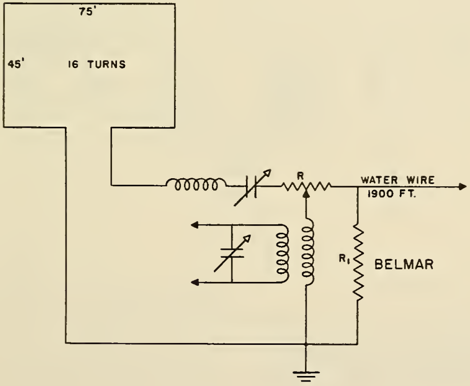


Figure M–6.

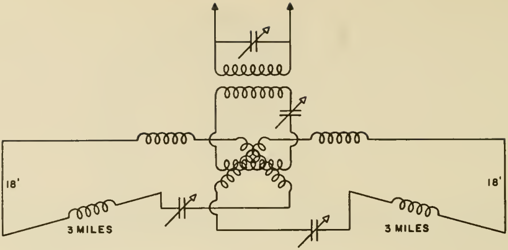


Figure M–7.

The Weagant Loop System

This system was developed by Dr. Roy A. Weagant, Chief Engineer of the Marconi Wireless Telegraph Co. of America, with assistance provided by Mr. George H. Clark who was detailed by the Navy for that purpose. It consists of two opposing single-turn loops whose extreme ends are exactly one-half a wavelength (of the signal to be received) apart. The two loops are coupled to the primary of the detector circuit by means of a triple-winding transformer in such a manner as to keep the static balanced out. This system, shown schematically in Figure M–7, was not used by the Navy but was universally hailed as the eliminator of static. The Radio Corp. of America utilized it on some of their circuits.

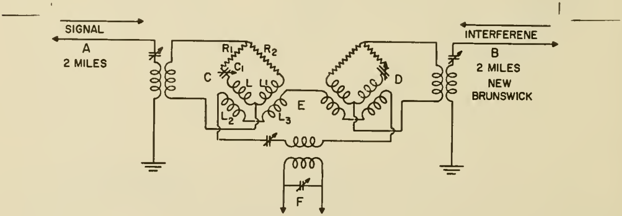


Figure M–8.

The Alexanderson Barrage System

This extremely directional system utilized two opposing, well insulated, wires each one-quarter wave in lengths of signal to be received. These wires extended horizontally, and could be underground, submerged in water, on the ground, or elevated. To eliminate interference from a nearby station the wires had to be placed on or very close to the line of bearing between the receiving and interfering stations and between them. It was developed by Mr. E. F. W. Alexanderson of the General Electric Co., famed for the development of the alternator bearing his name. He was provided with all the information possessed by naval engineers concerning the several antistatic systems and worked in close conjunction with them in its development. The schematic diagram is shown in Figure M–8.

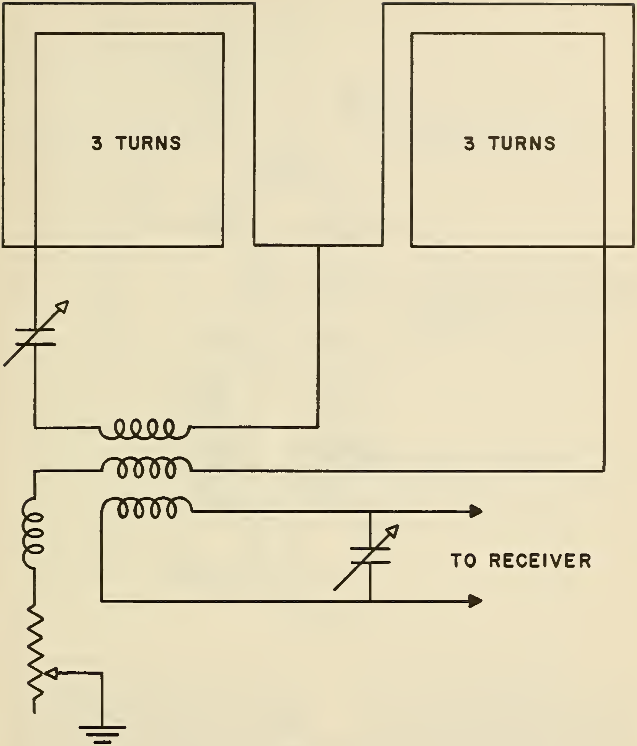


FIGURE M–9.

THE PROCTOR LOOP COLLECTOR SYSTEM

The Proctor loop collector system consisted of two diametrically opposed loops of three turns each, 30 feet high and 70 feet long, one of which had a variable amount of inductance in series with it and the other a variable amount of capacitance. By varying these it was possible to place the two loops out of phase. This system, which was used at Bar Harbor for transatlantic reception, is shown schematically in Figure M–9.

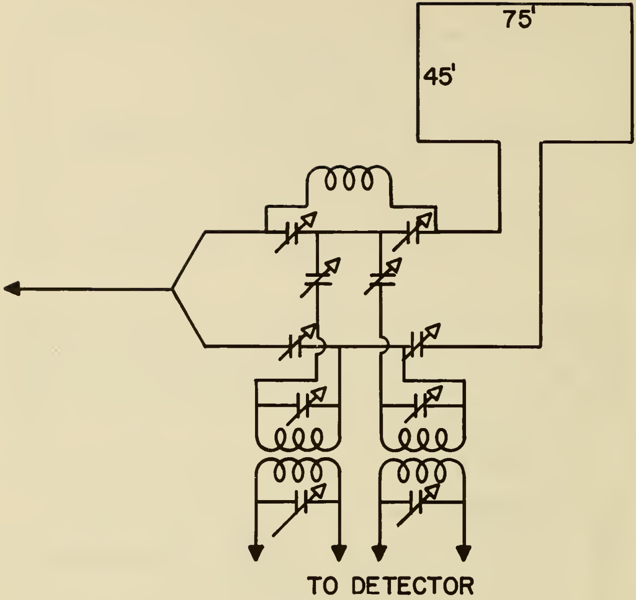


Figure M–10.

Multiplex Collector Systems—
The Austin Multiplex Collector System

Dr. L. W. Austin of the U.S. Naval Radio Laboratory designed several balanced antenna systems during the summer of 1918. The most important of these, the multiplex system, permitted coupling of as many as four detectors at varying frequencies to a single antenna thus allowing the simultaneous reception of four different stations. However, once tuned it had to be left untouched because the change of one circuit affects the tuning of all others. The schematic diagram of this system is shown in Figure M–10. It was used for transcontinental reception.

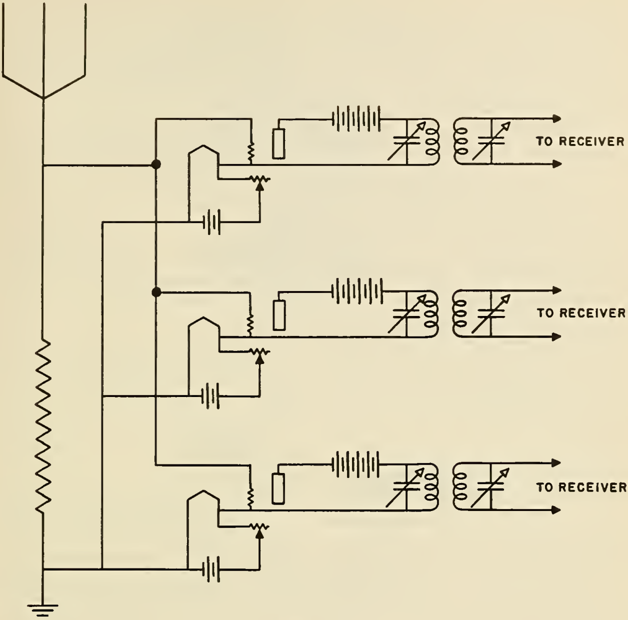


FIGURE M–11.

THE TAYLOR-YOUNG MULTIPLE RECEPTION CIRCUIT

The Taylor-Young multiple reception circuit was the first of this type of circuit to use vacuum tubes. It was much simpler to operate than the acceptor-rejector circuit and was not limited to dual reception. Frequencies could be shifted by any of the several operators without interfering with the tuning of the other primary circuits coupled to a single antenna. Additionally, this circuit, shown schematically in Figure M–11, reduced feedback in the reception of continuous waves. The vacuum tube in each of the primary circuits acted as a radiofrequency amplifier and coupler permitting energy to travel only in one direction, from antenna to primary coupling coil.

THE RADIO DIRECTION FINDER

The first satisfactory radio direction finder used by the U.S. Navy was the League Island (Philadelphia, Pa.) adaptation of a system devised by Dr. F. A. Kolster who utilized a frequency meter, also developed by him, in conjunction with a coil antenna which could be rotated through 360° of azimuth. The inductance coil of a wavemeter is replaced by the above-mentioned rotatable coil antenna. When the plane of the coil is parallel with the direction of wave travel maximum signal intensity obtains. Conversely, when the plane of the coil is normal to the direction of wave travel minimum signal intensity exists. Since the coil was rotatable through 360°

it produced two maxima 180° apart, and, likewise, two mimima separated by the same amount.

Following the Navy's purchase of rights under the Kolster patents the SE 74 radio direction finder was constructed and installed in battleships and later modified by the addition of the SE 75 compensating condenser. There were no provisions for amplifying the signal in this equipment nor no ready means of determining which of the two nulls indicated the correct target bearing. The only method available to decide this was to steam along the line of bearing and determine whether there was an increase or decrease on the strength of the transmitted signal.

It was discovered that the Kolster apparatus did not give the desired zone of minimum signal or null because the coil functioned additionally as an open oscillator and the induced current caused the zone of silence or null to be obscured by a residual signal of almost constant intensity. In order to eliminate this condition Mr. H. A. Ballentine, Radio Aid, League Island Navy Yard suggested the addition of a compensating condenser between grid and ground in order to artificially restore the circuit to balance. This condenser required thorough shielding, was of the continuously variable air-dielectric type and had a very small capacity at zero setting. Using this compensating condenser and by means of careful tuning a null could be obtained which was much easier to detect than the maximum signal strength.

During early 1916, Dr. L. W. Austin of the U.S. Navy Radio Laboratory studied the problem in an effort to determine a method of discriminating between either the two maxima or two minima positions. Utilizing the knowledge that when the direction-finder coil was in one position in line with the direction of wave travel the current induced in it flowed in one direction and that when it was rotated 180° the induced current flowed in the oppsite direction. He reasoned that by imposing another constant current induced into a vertical antenna by the same source the problem could be solved. Conducting experiments based on this theory he discovered that by fairly loose coupling of the two circuits the currents were additive with the coil in one direction and that they opposed each other when it was in the reversed position. If the coupling was too tight the antenna current was so much greater than the coil current that the latter had but little effect.

A direction finder system built in accordance with specifications drawn up based on this information provides an ideal equipment since it meets the following requirements:

Spectrum search with tight coupling between antenna and coil,

Determination of general direction with loose coupling between antenna and coil (unilateral method of obtaining bearings); and,

Accurate determination of direction with antenna circuit disconnected (bilateral method of obtaining bearings).

By early 1921 the several types of components of radio direction finding equipment had been grouped into four types:

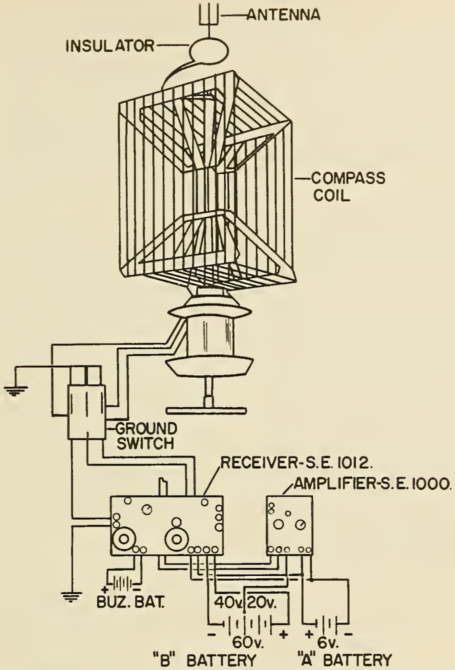
Group A, Shore Stations:
- SE 515A 6' coil, direct reading bearing dial;
- SE 1440 series receiver;
- SE 1672 compensating condenser; and the necessary ancillary apparatus.

Group B, Shore Stations:
- SE 515A 6' coil, direct reading bearing dial;
- SE 1012 receiver;
- SE 1000 or 1600 series two stage audio frequency amplifier;
- SE 1672 compensating condenser; and the necessary ancillary apparatus.

Group C, Ship Stations:
- SE 996 20" coil
- SE 1012 receiver or SE 998, receiver; in conjunction with CF 122 or 122A, vacuum tube detector;
- SE 999 rotary tone condenser;
- SE 997 20" coil housing; and the necessary ancillary apparatus.

Group D, Ship Stations:
- SE 1512 36" x 28" coil
- S– 1440 series receiver
- SE 1672 compensating condenser; and the necessary ancillary apparatus including a charging panel and a gyrocompass repeater.

In early 1918 the Radio Test Shop of the Washington Navy Yard designed the SE 950 aircraft direction finder receiver which was suitable for use either on a trailing wire antenna or on an aircraft direction finder coil. It had a frequency range of 250–1000 kc. and contained a two-stage audiofrequency amplifier as a component within the same package. A little later the SE 1012, with a frequency range 300–6000 kc., was designed for radio direction finder use in conjunction with the externally connected SE 1000 or 1600 series of audiofrequency amplifiers. Towards the end of 1918 and following the development of the SE 1420 neutrodyne receiver the SE 1440 autodyne receiver containing three stages of audiofrequency amplification frequency range 250–1200 kc. was developed for use with direction finders. This receiver was successively modified to include one stage of radiofrequency and two stages of audiofrequency amplification (SE 1440B) and finally to include one tuned radio stage, two transformer coupled radiofrequency stages and one detector (SE 1440C).



U.S. NAVY RADIO DIRECTION FINDER

Components and Connections

FIGURE M–12

Appendix N. Extracts from the Fourth International Radio-Telegraphic Convention

ARTICLE 1. SCOPE

1. The contracting Governments undertake to apply the provisions of the present Convention to all radio communication stations established, managed, or operated by the contracting Governments, and open to the international service of public correspondence. They also undertake to apply these provisions to the special services covered by the regulations annexed to the present Convention.

2. They also undertake to take or to propose to their respective legislatures the necessary measures to impose the observance of the provisions of the present Convention and the Regulations annexed thereto upon individuals and private enterprises authorized to establish and operate radio communication stations in international service, whether or not open to public correspondence.

3. The contracting Governments recognize the right of two contracting countries to organize between themselves radio communications, provided only that they conform to all provisions of the present Convention and the Regulations annexed thereto.

ARTICLE 8. INTERFERENCE

The stations covered by Article 1 must, so far as practicable, be established and operated under the best conditions known to practice and must be maintained abreast of scientific and technical progress.

All stations, whatever their purpose, must so far as practicable be established and operated in such a way as not to interfere with the communications or radio services of other contracting Governments and of individuals or of private enterprises authorized by these contracting Governments to carry on public radio communication service.

ARTICLE 9. PRIORITY FOR DISTRESS CALLS

Radio stations engaged in the mobile service shall be obliged to give absolute priority to distress calls, regardless of their origin, to answer such calls, and to take such action with regard thereto as may be required.

ARTICLE 21. RESERVATION AS TO NONREGULATED STATIONS

The contracting Governments retain their entire liberty regarding radio installations not covered in Article 1, and particularly to naval and military installations.

All these installations and stations must, so far as practicable, comply with the provisions of the regulation relative to the relief to be given in case of distress and to measures to be taken to prevent interference. They must also, so far as practicable, observe the provisions of the regulations concerning the types of waves and frequencies to be used, according to the type of service which these stations carry on.

When these installations and stations, however, exchange public correspondence or participate in special services governed by the Regulations annexed to the present Convention, they must, in general, conform to the provisions of the Regulations for the execution of these services.

EXTRACTS FROM GENERAL REGULATIONS ANNEXED TO THE INTERNATIONAL RADIOTELEGRAPH CONVENTION

ARTICLE 4.

1. Radio emissions are divided into two classes:

A. Continuous waves,

B. Damped waves,

defined as follows:

CLASS A. Waves the successive oscillations of which are identical under permanent conditions.

CLASS B. Waves consistilng of successive wave trains in which the amplitude of the oscillations, after having reached a maximum, decreases gradually.

Waves of Class A include the following types which are defined below:

Type A1: Unmodulated continuous waves. Continuous waves, the amplitude or frequency of which is varied by means of telegraphic keying.

Type A2: Continuous waves modulated at audible frequency. Continuous waves the amplitude or frequency of which is varied in a periodic manner at audible frequency, combined with telegraphic keying.

Type A3: Continuous waves modulated by speech or by music. Continuous waves, the amplitude or frequency of which is varied according to the characteristic vibrations of speech or music.

The above classification, into waves of Types A1, A2, and A3, shall not prevent the use, under conditions fixed by the administrations concerned, of modulated and (or) manipulated waves, by methods not falling within the definitions of Types A1, A2, and A3.

These definitions do not relate to systems of transmitting apparatus.

Waves will be desginated in the first place by their frequency in kilocycles per second (kc/s). Following this degsination there will be indicated, in parentheses, the approximate length in meters. In the present Regulations, and approximate value of the wave length in meters is the quotient of the number 300,000 divided by the frequency expressed in kilocycles per second.

2. Waves emitted by a station must be maintained upon their authorized frequency, as exactly as the state of the art permits, and their radiation must be as free as practicable from all emissions not essential to the type of communication carried on.

3. The interested administrations shall fix the tolerance allowed between the mean frequency of emissions and the recorded frequency; thy shall endeavor to take advantage of technical improvements progressively to reduce this tolerance.

4bix. The width of a frequency band occupied by the emission of a station must be reasonably consistent with good current engineering practice for the type of communication involved.

4. In cases where frequency bands are assigned to a specified service, stations in that service must use frequencies sufficiently remote from the limits of these bands, so as not to produce serious interference with the work of stations belonging to services to which are allocated immediately neighboring bands of frequencies.

Article 5. Allocation and Use of Frequencies (Wave Lengths) And Types of Emissions

1. The Administrations of the contracting countries may assign any frequency or any type of wave to any radio station within their jurisdiction upon the sole condition that it will result in no interference with any service of another country.

2. These Administrations, however, agree to assign to stations, which by their very nature are believed capable of causing serious international interference, frequencies and types of waves in conformity with the rules for allocation and use of waves as set forth below.

3. The Administrations agree also to consider the table of allocation of frequency bands (see par. 7) as a guide giving, for the different services, the limits which must be observed by all new stations and to which they shall adapt all existing stations with the least practicable delay, without diminishing the quality of the service which these existing stations carry on and taking into account the present state of their installations.

4. Nevertheless, the frequencies of all broadcasting stations now working on frequencies below 300 kc/s (wave lengths above 1,000 m.) shall, in principle, within a year following the coming into force of the present regulations, be removed either to the band included between 160 and 224 kc/s (wave lengths 1,875–1,340 m.) or to the band included between 550 and 1,500 kc/s (wave lengths 454–200 m.).

5. No new broadcasting station shall be authorized to work in the frequency band included between 160 and 224 kc/s (wave lengths 1,875–1,340 m.) unless no inconvenience therefrom will result to existing radio communication services, including broadcasting services carried on by the stations which are already using the frequencies included in this band and stations the frequencies of which shall be removed to the interior of this same band in conformity with the provision of paragraph 4 above.

6. The power of existing broadcasting stations using frequencies below 300 kc/s (wave lengths over 1,000 m.) shall not be increased unless no inconvenience will result to existing radio communication services.

7. The table below shows the allocation of frequencies (approximate wave lengths) among the various services:

8. (1) Use of waves of Type B of a frequency of less than 375 kc/s (wave length over 800 m.) will be forbidden beginning January 1, 1930, with the exception provided in paragraph 1 of the present Article except for existing land stations.

(2) No new installations of transmitters of waves of Type B shall be made in ships or in aircraft beginning January 1, 1930, except when these transmitters working on full power shall dissipate less than 300 watts measured at the input of the supply transformer at audible frequency.

(3) The use of waves of Type B of all frequencies will be forbidden beginning January 1, 1940, except for transmitters fulfilling the conditions as to power indicated in (2) above.

(4) No new installations of transmitters of Type B shall henceforth be made in a land or fixed station. Waves of this type shall be forbidden in all land stations beginning January 1, 1935.

9. The use of waves of Type A3 shall not be authorized between 100 and 160 kc/s (3,000 and 1,875 m.).

10. The use of waves of Type A2 shall not be authorized between 100 and 150 kc/s (3,000 and 2,000 m.), except in the band of 100–125 kc/s (3,000–2,400 m.), for time signals exclusively.

11. In the band 460–550 kc/s (650–545 m.) no

type of emissions likely to render inoperative the signals of distress, of alarm, of securtiy, of urgency sent on 500 kc/s (600 m.) shall be authorized.

12. In principle every station carrying on a service between fixed points on a wave of frequency below 110 kc/s (wave lengths over 2,725 m.) must use a single frequency chosen from the bands allocated to that service (par. 7 above), for each of the transmitters which it possesses and which are capable of simultaneous operation. A station shall not be permitted to use, for a service between fixed points, a frequency other than that allocated, as stated above.

13. In principle stations shall employ the same frequencies and the same types of emission for the transmission of messages by the one-way system as for their normal service. Regional arrangements may be made, however, with a view to exempting stations concerned from this rule.

14. With a view to facilitating the exchange of synoptic meterological messages in European regions, two frequencies between 37.5 and 100 kc/s (wave lengths of 8,000–3,000 m.) shall be allocated to this service by regional arrangements.

15. To facilitate transmission and rapid distribution of information of value in the detection of crime and pursuit of criminals, a frequency between 37.5 and 100 kc/s (wave length 8,000–3,000 m.) shall be reserved for this purpose by regional arrangements.

16. The frequencies assigned by Administrations to all new fixed land or radio broadcasting stations which they may have authorized or of which they may have undertaken the installations must be chosen in such a manner as to prevent as far as possible interference with international services carried on by existing stations the frequencies of which have already been notified to the International Bureau. In a case of change of frequency of an existing fixed land or broadcasting station, the new frequency assigned to this station must comply with the above conditions.

The interested Governments shall agree, in case of need, upon the fixing of waves to be assigned to the stations in question as well as upon the conditions for the use of waves so assigned. If no arrangement intended to eliminate interference can be arrived at, the provisions of Article 18 of the Convention may be applied.

17. Each Administration shall advise the International Bureau without delay when it decides upon or authorizes the establishment of a radio communication station, the operation of which necessitates the assignment for its regular service, of a particular frequency below 37.5 kc/s (of a wave length above 8,000 m.) in the case where the use of this frequency might cause international interference over broad areas. This notice must reach the International Bureau four months before the construction of the station contemplated so as to take care of objections which any of the administrations might raise against the adoption of the proposed frequency.

In the case of a fixed short wave station intended to carry on a regular service and the radiation of which is likely to cause international interference, the Administration concerned must, as a general rule, before the completion of a station and in any case before it is open for service, advise the International Bureau of the frequency assigned to the station.

Such a notification shall, however, be sent only when the Administration concerned shall have ascertained that the service in question can be established within a reasonable time.

18. Each Administration may assign to amateur stations frequencies chosen from the band allocated to amateurs in the allocation chart (par. 7 above).

The maximum power which these stations may use shall be fixed by the administration concerned taking into account the technical abilities of the operators and the conditions under which the stations must function.

All the general rules fixed in the Convention and in these Regulations apply to amateur stations. In particular, the frequency of the waves emitted must be as constant and as free from harmonics as the state of the art permits.

In the course of their transmission these stations must transmit their call signals at frequent intervals.

Article 18. Conditions to be Observed by Mobile Stations

1. Mobile stations must be established in such a way as to conform, with reference to frequencies and types of waves, with the general provisions constituting the subject matter of Article 5. In accordance with these provisions, the use by mobile stations of damped waves (Type B) of a frequency below 375 kc/s (wave length above 800 m.), shall be forbidden beginning January 1, 1930.

In addition, no new installations of transmitters of Type B waves shall be made in mobile stations after January 1, 1930, except when these transmitters working on full power shall expend less than 300 watts measured at the input of the supply transformer at audible frequency.

Finally, the use of Type B waves of all frequencies shall be forbidden beginning January 1, 1940, with the exception of transmitters fulfilling the same conditions regarding power as above.

2. Every station installed on board a vessel or an aircraft following a maritime route, such vessel or aircraft being compulsorily equipped with radio apparatus in accordance with an international agreement, must be able to send and receive on a wave of 500 kc/s (600 m.) type A2 or B.

Ship stations must, in addition, be able to use the wave of 375 kc/s (800 m), type A2 (or B subject to paragraph 1 above).

Aircraft stations must be able to send and receive the wave of 333 kc/s (900 m.) Types A2 or A3 (or B subject to the provisions of Paragraph 1 above).

3. In addition to the fixed waves stipulated above,

mobile stations equipped for the sending of waves of Types A1, A2 or A3 may use all the waves authorized in article 5.

The use of waves of Type B is authorized only for the following frequencies (wave lengths):

Kc/s	*Meters*	*Kc/s*	*Meters*
375	800	500	600
410	730	665	450
425	705	1000	300
454	660	1364	220

The use of the Type B wave of 665 kcs (450 m.) is forbidden from now on in regions where this wave may interfere with broadcasting.

The use of the type B wave of 1000 kcs (300 m.) for traffic is forbidden, from now on, between 6:00 p.m. and midnight, local time, and shall be entirely forbidden, at all times, beginning January 1, 1930 at the latest. This same Type B wave of 100 kcs (300 m.) may, however, continue in use indefinitely without restriction as to hours, by stations on board fishing vessels, for radiocompass bearings between one another, on condition of not interfering with broadcasting.

4. All apparatus in mobile stations established for the transmission of waves of Type A1 between 125 and 150 kcs (2400–2000 m.) must permit the use of at least three frequencies chosen from this band, and must permit a rapid change from one to another of these frequencies.

5. All stations on ships compulsorily equipped with radio apparatus must be able to receive the wave of 500 kcs (600 m.) and in addition all the waves necessary to the proper accomplishment of their services.

Beginning January 1, 1932 they must be able to receive easily and efficiently on the same frequencies, waves of Types A1 and A2.

6. Transmitting apparatus used in the mobile service must be provided with devices permitting reduction of power. This provision does not apply to transmitters, the input power of which does not exceed 300 watts.

7. Receiving apparatus must be such that the current which it produces in the antenna shall be as small as possible and will not disturb neighboring stations.

8. The transmitting and receiving apparatus of all mobile stations must be such as to allow changing of frequency as rapidly as possible. All installations must be such that communications once being established the time necessary to change from transmission to reception and vice versa will be as short as possible.

ARTICLE 19. CALLING AND LISTENING WAVES

1. In the band included between 360 and 515 kcs (830 and 580 meters) the only waves of type B allowed are the following: 375, 410, 425, 454, and 500 kcs (800, 730, 705, 660, 600 m).

The general calling wave, which must be used by all ships compulsorily equipped and by coast stations, is 500 kcs (600 m) (A1, A2 or B).

Besides the frequency 500 kcs (600 m) the use of waves between 485 and 515 kcs (620 and 580 m) is forbidden, of any type.

The frequency of 500 kcs (600 m) is the international calling and distress. It may be used, but with discretion for other purposes, if it does not interfere with distress, urgent, safety, or call signals.

Coast stations must be able to use at least one wave besides that of 500 kcs (600 m). This additional wave shall be underlined in the Nomenclature to indicate that it is the normal working wave of the station. The additional waves thus chosen may be the same as those of ship stations or may be different. In any case, the working waves of the coast stations must be chosen in such a way as to avoid interference with neighboring stations.

Besides the normal working waves underlined in the Nomenclature, coast and ship stations may use additional waves in the authorized band as they consider convenient. These waves shall be published in the Nomenclature without being underlined.

4. (1) In order to increase safety of life at sea (ships) and above the sea (aircraft), all stations in the mobile maritime service must, during their hours of service, take the necessary measures to assure the watch on the distress wave (500 kcs-600 m) twice per hour for three minutes, beginning at the 15th minute and at the 45th minute after each hour Greenwich Mean Time.

(2) Stations carrying on a service of radiotelegraph correspondence, press news, etc., with ships at sea must observe silence during the intervals indicated above. Only the transmissions provided for in Article 21, Paragraphs 25 to 27, may be made during these intervals.

(3) As an exception, however, land and ship stations equipped to correspond by means of continuous waves may continue to work during these periods; if they are in a position to maintain at the same time a satisfactory watch on the distress wave as provided for in subparagraph (1) of the present paragraph.

6. The following rules shall be observed in the operation of stations in the mobile service using waves of type A1 in the band 100 to 160 kcs (3000 to 1875 m) which is assigned to the mobile service.

(a) Every coast station carrying on communication on a long continuous wave must listen on the wave of 143 kcs (2100 m) unless it is otherwise indicated in the Nomenclature. The coast station shall transmit all its traffic on the wave or waves which are especially assigned to it.

(b) When a mobile station desires to establish communication on a long continuous wave with another station of the mobile service, it must employ the frequency of 143 kcs (2100 m) unless it is otherwise indicated in the Nomenclature. This wave, designated as the general communication wave, must be employed:

1. For calls and answers thereto.

2. For sending signals preliminary to the transmission of traffic.

(c) A mobile station after having established communication with another station in the mobile service, on the general communication wave, may transmit its traffic on any wave in the authorized band on condition that it does not disturb the work of a coast station or work in progress on the calling wave.

(d) As a general rule, every mobile station, equipped for service on long continuous waves and not engaged in communication on another wave, must, in order to permit the exchange of traffic with other stations of the mobile service, return to the wave of 143 kcs (2100 m) for 10 minutes from the beginning of the 35th minute to the beginning of the 45th minute of each hour, Greenwich Mean Time, during the specified hours, according to the class to which the station in question belongs.

(e) Coast stations shall transmit their traffic lists at specified times, published in the Nomenclature, on the wave or waves which are assigned to them.

Besides the times thus fixed for this transmission of their traffic lists, coast stations may call mobile stations, individually at any other time, according to circumstances or according to work which they have to carry on. These individual calls may be made on the wave of 143 kcs (2100 m) in areas where there is no congestion of traffic.

(f) The special provisions concerning the service carried on by land stations using long continuous waves shall be shown in detail in a special reference in the Nomenclature.

Frequency Assignments By Service

Frequencies in kilocycles per second	*Services*
10–100	Fixed services.
100–110	Fixed services and mobile services.
110–125	Mobile services.
125–150 [1]	Maritime mobile services for public correspondence exclusively.
150–160	Mobile services: (a) Broadcasting. (b) Fixed services. (c) Mobile services.
160–194	The conditions for use of this band are subject to the following regional arrangements: All regions where broadcasting stations now exist working on frequencies below 300 kc./secs broadcasting. Other regions fixed and mobile services. Regional arrangements will respect the rights of other regions in this band. The conditions for use of this band are subject to the following regional arrangements: (a) Air mobile service exclusively. (b) Air fixed services exclusively. (c) Within the band 250–285 kc.
194–285	Europe. (1200—1050 m.). Fixed service not open to public correspondence. Other regions: (a) Mobile services except commercial ship stations. (b) Fixed air services exclusively. (c) Fixed services not open to public correspondence.
285–315	Radio beacons.
315–350 [2]	Air mobile services exclusively.
360–390	Mobile services not open to public correspondence: (a) Radio direction finding. (b) Mobile services, on condition that they do not interfere with radio direction finding.
390–460	Mobile services.
460–485	Mobile services (except damped waves and radiotelephony).
485–515 [3]	Mobile services (distress, call, etc.).
515–550	Mobile services not open to public correspondence (except damped waves and radiotelephony).
550–1,300 [4]	Broadcasting.
1,300–1,500	(a) Broadcasting. (b) Maritime mobile services, waves of 1365 kc./sec. (220m) exclusively.
1,500–1,715	Mobile services.
1,715–2,000	Mobile services. Fixed services. Amateurs.
2,000–2,250	Mobile services and fixed services.
2,250–2,750	Mobile services.
2,750–2,850	Fixed services.
2,850–3,500	Mobile services and fixed services.
3,500–4,000	Mobile services. Fixed services. Amateurs.
4,000–5,500	Mobile services and fixed services.
5,500–5,700	Mobile services.
5,700–6,000	Fixed services.
6,000–6,150	Broadcasting.
6,150–6,675	Mobile services.
6,675–7,000	Fixed services.
7,000–7,300	Amateurs.
7,300–8,200	Fixed services.
8,200–8,550	Mobile services.
8,500–8,900	Mobile services and fixed services.
8,900–9,500	Fixed services.
9,500–9,600	Broadcasting.

9,600–11,000	Fixed services.
11,000–11,400	Mobile services.
11,400–11,700	Fixed services.
11,700–11,900	Broadcasting.
11,900–12,300	Fixed services.
12,300–12,825	Mobile services.
12,825–13,350	Mobile services and fixed services.
13,350–14,000	Fixed services.
14,000–14,400	Amateurs.
14,400–15,100	Fixed services.
15,100–15,350	Broadcasting.
15,350–16,400	Fixed services.
16,400–17,100	Mobile services.
17,100–17,750	Mobile services and fixed services.
17,750–17,800	Broadcasting.
17,800–21,450	Fixed services.
21,450–21,550	Broadcasting.
21,550–22,300	Mobile services.
22,300–23,000	Mobile services and fixed services.
23,000–28,000	Not reserved.
28,000–30,000	Amateurs and experiments.
30,000–56,000	Not reserved.
56,000–60,000	Amateurs and experiments.
Above 60,000	Not reserved.

[1] The wave of 143 kc/s (2,100m) is the calling wave for mobile stations using long continuous waves.

[2] The wave of 333 kc./sec. (90 m.) is the international calling wave for air services.

[3] The wave of 500 kc./sec. (600 m.) is the international calling and distress wave. It may be used for other purposes on condition that it will not interfere with call signals and distress signals.

[4] Mobile services may use the band 550 to 1,300 kc./sec. (545–230 m.) on condition that this will not cause interference with the services of a country which uses this band exclusively for broadcasting.

Note: It is recognized that short waves (frequencies from 6,000 to 23,000 kc./sec., approximately—wave lengths from 50 to 13 m. approximately) are very efficient for long-distance communications. It is recommended that, as a general rule, this band of waves be reserved for this purpose, in services between fixed points.

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