Auroral Chorus III: Music of the Magnetosphere

VLF Radio sounds descriptions pertaining to these two CD's

Man-made VLF emissions:

Lightning-stroke" static": If you've already listened to ANY of these recordings, you will have certainly noticed (or may even be fed-up with) the nearly constant crackling and popping noises on each and every one of these CD's tracks. An unavoidable part of recording natural VLF radio from ground-level (versus orbiting satellites), lightning static is ALWAYS audible, though, depending on the location and time of year, the amount of lightning static can widely vary.

Generally, recordings made in local summer are plagued with lightning-storm static and those made in mid-winter tend to be wonderfully quiet. While a nuisance to some listeners, VLF lightning static is trying to tell us something. Imagine a bolt of lightning--say, a bolt of lightning that strikes the ground from a cloud above. The length of this awesome spark can be many miles long and as wide as an automobile.

Between 10,000 to over 100,000 volts are generated in this instantaneous jolt. Furthermore, a single lightning bolt rarely fires just once, but as much as 100 times a second, giving it that "flickering" effect. As such; each and every one of those innocent "pops" evident in these recordings is one of those huge sparks just described. But as you may have already observed, there are seemingly HUNDREDS of them per second occurring in many of the recordings, some of them really loud, but most quite moderate to faint. They seem to permeate the background--sort of like playing an old, worn vinyl record.

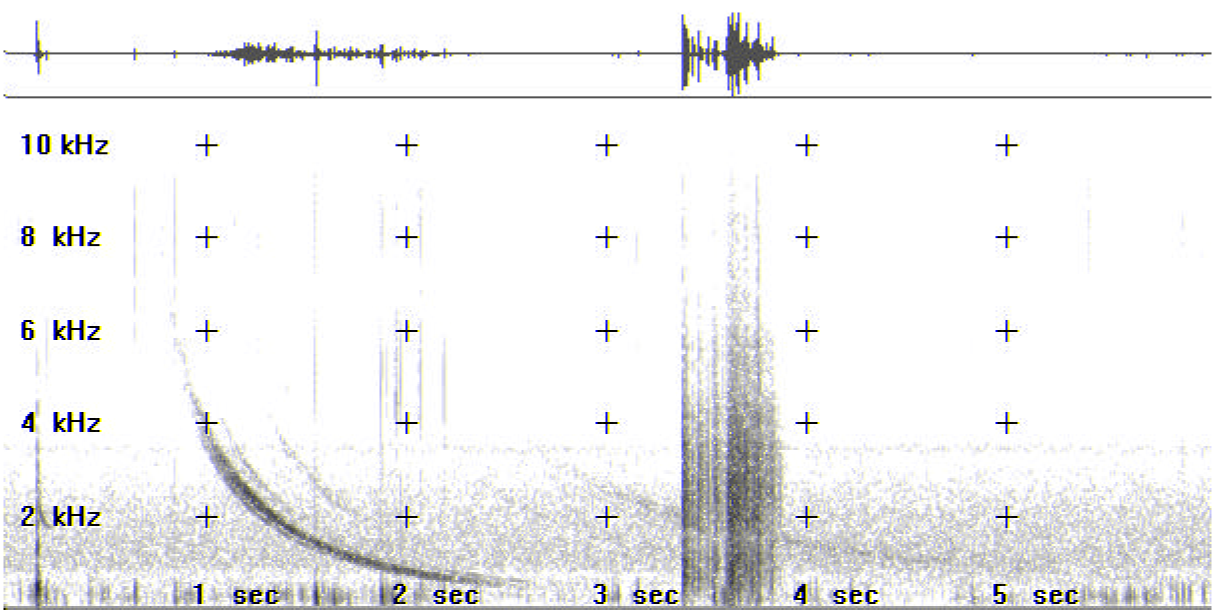
Obviously, there is A LOT of lightning zapping away out there! And the figures agree: there are a couple million lightning strokes (flashes) occurring each day, worldwide, from approximately 1500-2000 lightning storms in progress at any given time. A VLF receiver is quite good at picking up lightning from as far as 3000 miles distant (perhaps more), and gives you a nice idea of the SHEER amount of lightning strokes firing off in any given second! You may experience days or weeks of sunny, delightful weather where you live, but the VLF receiver NEVER lets you forget that lightning is lurking all 'round you!

Tweeks: You might have already noticed a lot of the lightning static “sferics” seems to have odd pinging and ringing characteristics. This “tweeking” effect, sometimes quite beautiful sounding (such as in the Fish Rock Road Whistlers track), is generally a nighttime effect, with a few tweeks audible in the late afternoon/early evening and reaching their best and most numerous around midnight, and finally tapering off once sunrise occurs.

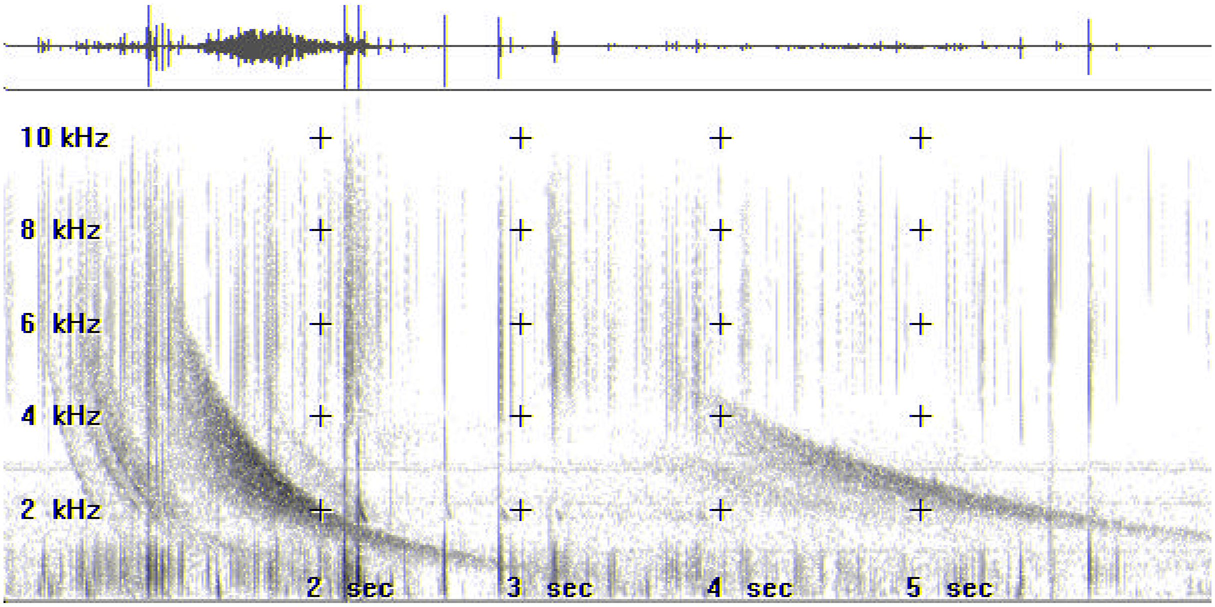
At about 50-55 miles in altitude (80-88 km), the E-layer of Earth's ionosphere (a layer of charged particles, called ions) acts similar to a mirror or as a really thick lens to VLF radio waves. The same goes for Earth's surface (more- or-less) and the two “sides” form a sort of pipeline which channel VLF radio signals, especially lightning stroke static impulses. Static impulses from very distant lightning storms (thousands of miles) can travel better at night in this huge radio wave pipeline of Earth, but, below a certain frequency, there is an abrupt cut-off, whereby the pipeline effect ceases. This is at about 1700 Hz audio frequency, which is also the frequency which most of the ringing and pinging sounds of tweeks are taking place. A good example of tweeks is in Track 2 of Disc Two.

Tweeks slowed down about 10 times almost begin to mimic low-pitched whistlers! Like Whistlers, one can get lost in the explanation of what causes a Tweek, and so it's sometimes more fun just to enjoy their odd sounds. Also like Whistlers, Tweeks can sound very different from night-to-night, sometimes very pure and ringy, other nights they have a “crusty” sound. During those (frequent) times no other Natural Radio sound can be heard besides incessant static, listening to Tweeks themselves can be mesmerizing!!

Whistlers: Most people get introduced to Natural Radio by hearing a recording of a whistler, as I was back in the late 1980’s. Indeed, whistlers are the most common Natural VLF Radio sound besides lightning static for those listening in middle latitudes such as California or Nevada. The term “whistler” broadly defines downward- falling sounds which range from nearly pure whistling tones to windy/breathy sounds more similar to a “sigh” than a whistle. Between these extremes are a vast variety of whistler types. You’ll hear a plentiful variety of whistlers on these two CD’s.



Nearly pure-tone whistler with echo - Track 20, Disc One - central Nevada 17 Sept. 1999. Initiating lightning static impulse is seen at far left at near the 0-second mark.



Diffuse whistler complex with echo - Track 18, Disc One - Inyo County Calif. 01 April 2001

In the case of the whistlers recorded in the eastern Nevada high desert April 1996, I called those whistlers “growlers,” since they sounded more like growls than whistles. Of course, there are many samples of whistlers in these CD's. Whistlers are the direct result of a lightning stroke firing off, and usually occur 1-2 seconds after an initiating lightning flash. Very few of any lightning strokes ever produce whistlers, but enough do to make things very interesting on the good days, and sometimes whistlers are so numerous as to be called “Whistler Showers” or even “Whistler Storms.”

Earth's magnetic field, which keeps compasses nicely pointing in one direction only (usually!), plays a major role in the formation of whistlers. Not fully understood to this day, the traditional theory assumes that SOME of the radio energy from SOME of the lightning strokes in just the RIGHT location get “ducted” into channels formed along the lines of Earth's magnetic field (within the magnetosphere), traveling out into near space and to the opposite hemisphere, where they are heard as a short, fast whistler “1-hop whistler.”

If conditions are favorable, some of the energy from these short, fast whistlers rebounds back the way it came to “arrive near” (within several thousand miles of) the point of its initiating lightning stroke, and becoming magically louder and longer. It is believed that there is some sort of amplification effect happening within Earth’s magnetosphere - somewhat like a vacuum tube amplifier. Essentially, during its globe- hopping round trip, the “all-frequencies-at-once” radio signal of a lightning static “pop” gets the privilege of being pulled and stretched apart, with its higher audio frequencies arriving sooner than its lower frequencies, hence the downward-falling tone. Whistlers can make more than one round-trip. Frequently, at least one “echo” following a whistler will occur.

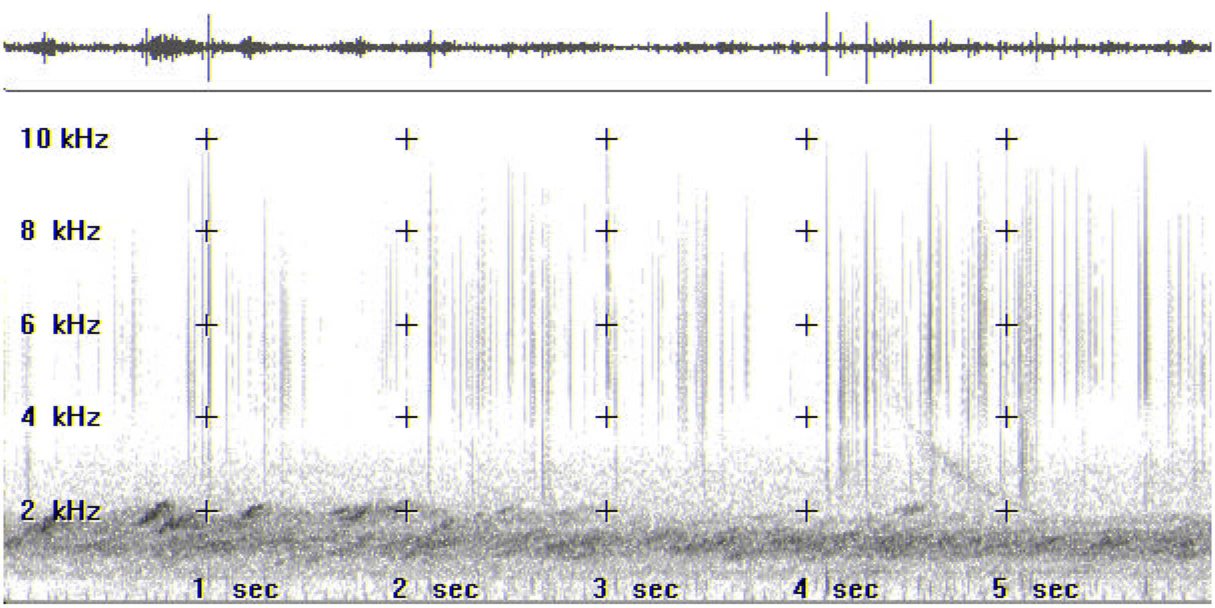
Shawn Korgan in Colorado: There are many such “whistler-echo” events on these CD’s tracks, but the finest examples of multiple-echoing whistlers is Shawn Korgan’s three-minute compilation he sent me earlier in 2001 of fabulous whistler “echo-trains” intermixed with chorus and other natural VLF emissions. I very appreciate his enthusiastic granting of my request to him to include one of his many outstanding recordings from northeastern Colorado he has been sending me all year. I specifically asked him if I could include his whistler recordings on the morning of 01 April 2001 - the morning following an immense magnetic-storm that spawned lovely auroras seen down to Mexico, and which I photographed over my house in Inyo County, California early the morning of 31 March 2001. Three tracks of resultant natural VLF radio sounds are in Disc One’s Tracks 17 and 18 recorded by S. P. McGreevy in Inyo County, California; and Track 19, recorded by Shawn Korgan in northeastern Colorado. Fine examples of whistlers triggering furious bursts of chorus is in Shawn’s recording in Track 19 - clearly, Shawn was closer that me to the VLF action on 01 April 2001!

Another fascinating aspect to whistlers is that (on nights or days when they are occurring, and ideally at a rate of several per-minute) their sound characteristics will vary--sometimes highly--at different listening locations, especially along the same magnetic longitude (the direction north and south to where a compass needle points). Thus, “growler” whistlers occurring loudly at a listening site in Nevada likely will probably have hissy and breathy sounds, or perhaps not, in

Saskatchewan 1000 miles to the north-northeast In southern Montana, the same whistler may sound something in-between the Nevada and Saskatchewan characteristics. Interestingly, the region where the most frequent and strongest whistlers are monitored (on average) lies in a zone roughly 700 to 1000 miles equatorward of where chorus and other natural VLF radio emissions (further described below) tend to be most strongest and numerous (that being in and just south of the auroral zone, such as in northern Alberta and central/northern Saskatchewan to where I have made recording expeditions you are hearing in these two CD's).

Some, if not MOST days are DEAD--entirely devoid of the sounds of whistlers, but there can be those less frequent mornings where whistlers rain down too many to count, as though a huge switch was thrown by somebody "up there." Listen to the recordings, and you get the idea...

Chorus: Another general term used to define a number of Natural VLF Radio sounds, chorus defines several types of emissions when they occur in a rapid, intermixed form. The individual squawks, whoops, barks, and chirps of "triggered emissions" tend to get lumped into the general term of "chorus" when they occur in large amounts together (see "Triggered Emissions" further below). Frequently, individual components of chorus are called "risers" because they rise abruptly in pitch, rather than fall. Track 8 on Disc One (dawn chorus in Saskatchewan), 11 on Disc Two (Waterton Park, Alberta chorus) and also on portions of Track 19 of Disco One, is a classic example of the more common-sounding type of "dawn chorus" because it is heard most frequently during magnetic-storm periods around sunrise. Dawn chorus is more widely heard toward the more southerly latitudes such as the central US or Europe than chorus occurring at other times of the day, such as the nighttime chorus recorded in British Columbia's Vancouver Island in Track 25 of Disc One. I coined the term "Auroral Chorus" for chorus and chorus-like sounds I frequently record right through the day past noon in areas within the auroral-oval region of Canada and Alaska. Both dawn chorus and auroral (zone) chorus sound generally similar, though chorus can manifest itself in endless variety.



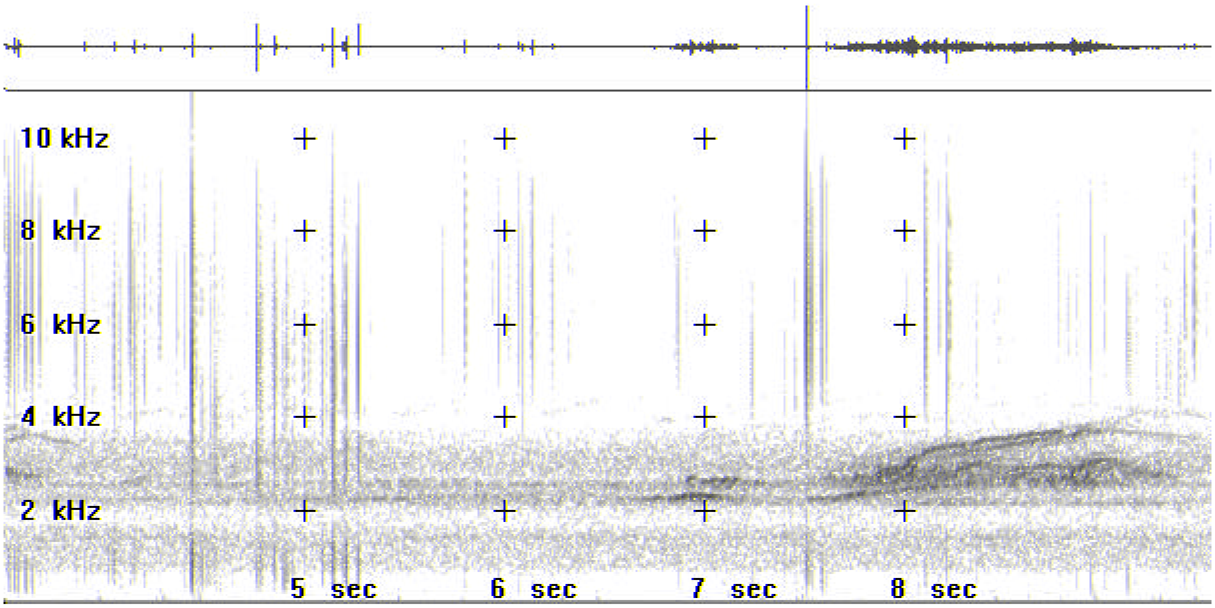
Chorus consisting of mainly risers, accompanied by a whistler - so. Alberta 08 July 2001, Track 11, Disc Two

When heard at middle latitudes such as in California, Nevada, etc., chorus is a product of magnetic storms when events on the Sun (such as a solar flare or "holes" in the Sun's outer atmosphere, the Corona) allow a barrage of high-speed charged particles to impact Earth's outer magnetic field (magnetosphere), causing it to deform and pulsate, much like air currents deform the thin film of a soap bubble. These "coronal mass ejections" are mostly responsible for the visual phenomena we can see and photograph such as aurora Northern and Southern Lights. Great events of natural radio phenomena also increase also dramatically during magnetic storm periods, as do such natural VLF Radio sounds such as chorus. In very high latitudes within the auroral-zone, chorus heard nearly daily when there is even a minor disturbance in the geo-magnetic field.

Notice the similarities of the various Chorus events presented on these two CD's, yet also notice the great variations. Short-lived repeating bursts of the individual sound components of chorus are sometimes referred to as "chorus trains " Auroral

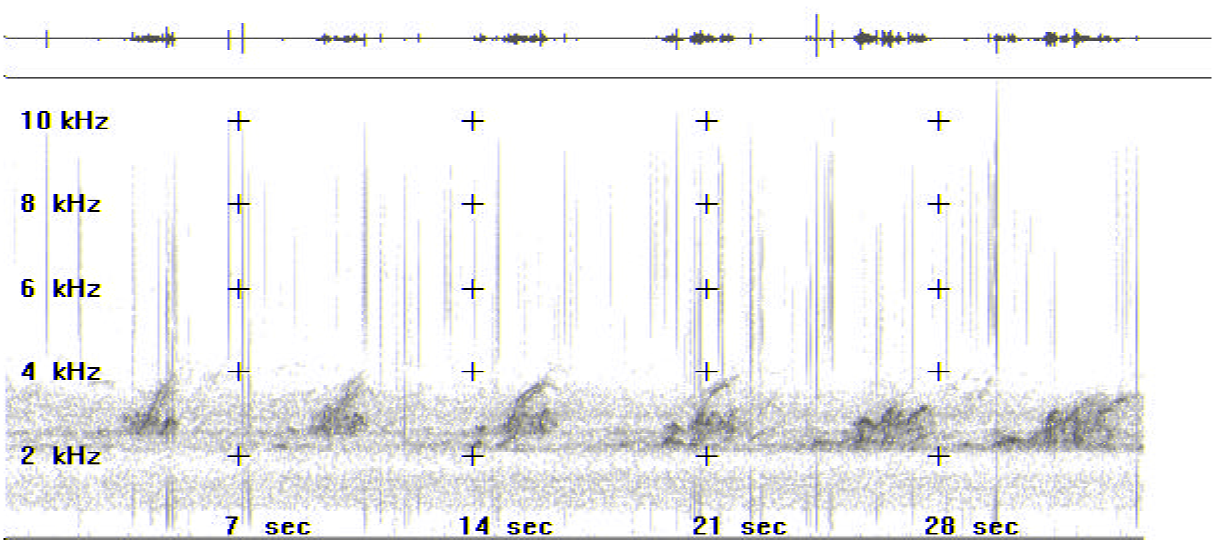
Chorus tends to be heard more often and at generally higher latitudes than whistlers, except for the widespread Dawn Chorus, which, when heard at lower-middle latitudes, is strictly a magnetic-storm time phenomena.

Hiss: Also called "hissband," is a VLF radio emission generated farther out in Earth's magnetosphere including the bow-shock region of the magnetosphere facing the incoming Solar Wind, although during very bright displays of aurora, it can be herd as a weak high-pitched sound.



Hissband, tonal-bands and periodic emissions on Track 7, Disc Two - recorded in Saskatchewan 29 June 2001.

An expanded view of this same event appears below notice the two distinct bands of hissband.



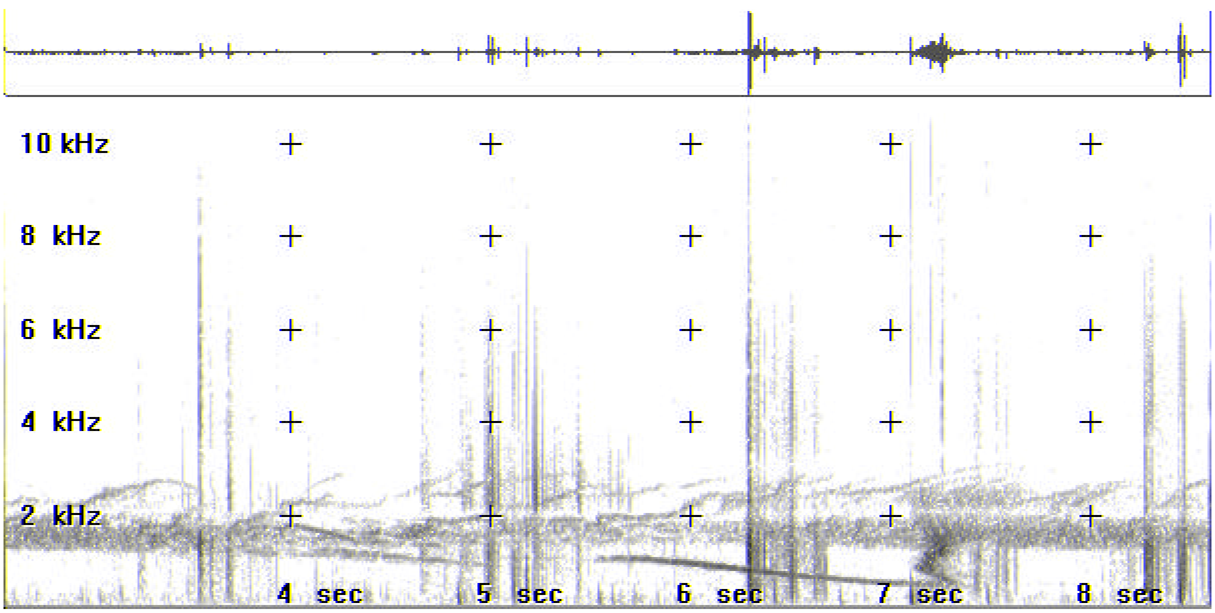
Hiss can vary in its frequency band, sometimes it has a high-pitched sound like a slightly open water valve or toilet-tank filling up, and on other occasions can sound much like the low-pitched roar of a waterfall.

While generally stable in characteristic, hissband can sometimes abruptly change in volume and/or pitch (listen to Track 5, Disc One, first minute), indicating some sudden change (such as an auroral substorm) has occurred in the geo-magnetic field amongst the complex electrical process happening within Earth's vast magnetosphere. Whistlers and other natural VLF radio emissions can affect and cause gradual or abrupt changes in hissband characteristics and can also trigger other emissions. Hissband is very frequent within auroral-zone areas, but is more seldom heard in California-latitudes except during major magnetic storms. At higher latitudes within the auroral-zone region, it tends to be heard most frequently during the daylight hours. Notice that hissband of many pitches (center frequencies) is on many of the spectrograms (and in most of the Canadian recordings) on these two CD's.

Hissband can also undulate rhythmically in over a span of several seconds - this can be either very diffuse "fuzzy," whistler echo-trains, or they can be actual fluctuations of hissband traveling in the same method whistlers travel. Listen carefully to the relatively low-pitched hissband in Track 6 of Disc One (northern Alberta) alongside a good mixture of other emissions.

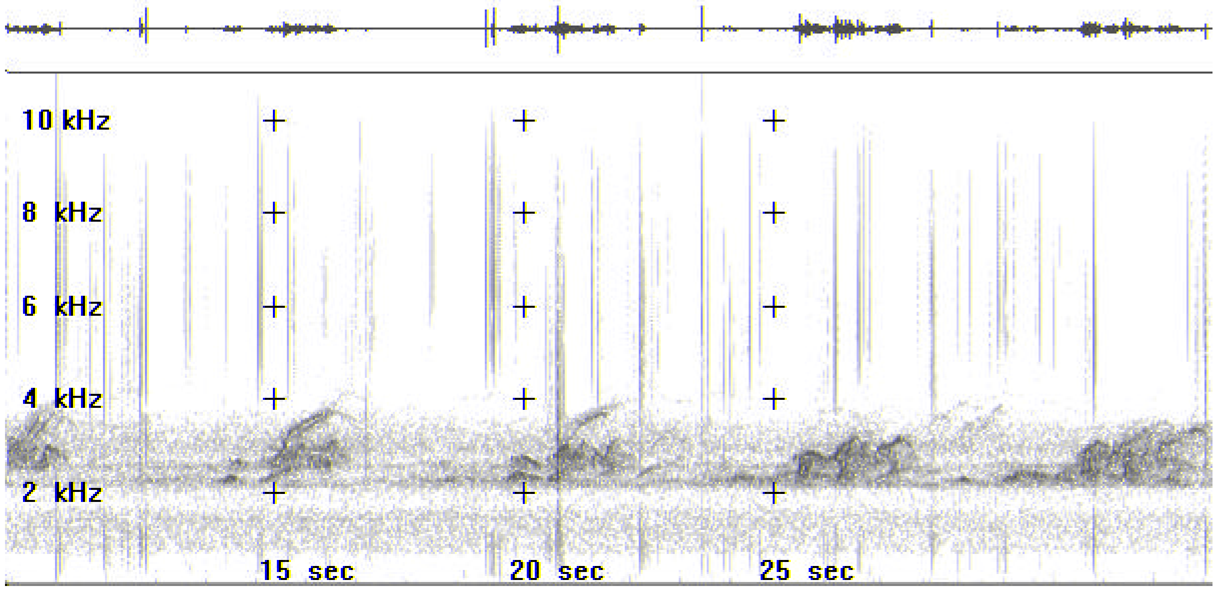
Periodic Emissions: Other sounds different than whistlers or chorus get lumped into this category, but as the term implies, they tend to occur only occasionally (periodically) and in repetitious fashion with a somewhat predictable repetition time (period). Phenomena lumped under this category appear in several tracks on both these CD's. A fine example of one of these this sounds is in Tracks 1 and 3 of Disc One - a phenomenon recorded in northern Alberta called **"hooks"** because they fall then abruptly rise in pitch. Notice that these "hooks" in tracks seem to trigger subsequent ones (rather like a good tennis volley) as it reaches a fast fury, then winds down to slower levels. Yet another good track of occasional hooks mixed in with other phenomena is in Track 8 of Disc 2, recorded in Saskatchewan. Hooks are less-common Natural Radio emissions arising from magnetic storm/auroral phenomena and heard this strongly **only** at higher latitudes such central or northern Canada and other locations near or within the auroral zone. Various periodic emissions such as hooks and other phenomena are also presented in Tracks 2, 5, 7, and 11 of Disc Two, recorded in Saskatchewan, Canada.

"Pseudo-whistlers:" There is a fine examples (in Tracks 1 and 3 of Disc One recorded in northern Alberta 12 August 2000) of downward falling tones that are not true whistlers, but are called "pseudo-whistlers" because, while they do fall in pitch, three origin is not from lightning but from processes farther out in space, nor do they have the known characteristics of true whistlers.



Above: Spectrogram of hooks from track 1, Disc One, recorded in northern Alberta 13 Aug. 2000

Below: Expanded view of periodic emissions in a 6-second cycle of repetition taken from Track 7, Disc Two. The bunches of slow risers and what have been called" inverted hooks" recorded in Saskatchewan 29 June 2001.



Tonal Bands: Strange-sounding whistling and musical noises, or a multitude of whistling sounds which abruptly begin and end, usually for usually a few to several seconds in duration. Many of these can be heard in the various tracks of these two CD's, but one of the finer examples of tonal bands slowly rising in pitch over and over - also periodic emissions, are on Tracks 6 and 7 of CD Two, both tracks recorded in Saskatchewan on 29 June 2001. They repeat at about the same rate that it would take for a whistler to make a full two-hop round-trip, so it is thought that these signals are propagated and sustained in a manner called "whistler mode," following the same or similar paths along whistlers within Earth's magnetosphere. Scientists also use the term "discrete emissions" to describe any number and variety of natural VLF radio emissions that have more of a narrow range of audio frequencies, such as chorus risers, hooks, and tonal bands, to name a few). Emissions such as hissband, that are more spread out spectrally, are not lumped under the term.

Triggered Emissions: a variety of natural VLF radio emissions seem to be triggered by a similar or differing VLF emission. Whistlers can trigger other emissions--often risers--that can carry on for a while after the whistler has passed. A fine example of hissy whistlers triggering risers that then carry on for many repetitions is in Track 4 of Disc Two, recorded in Saskatchewan on 23 June 2001.

The spectrograms are as beautiful as the natural VLF radio sounds!

Man-made VLF emissions:

Omega and Alpha: A couple of the recordings presented on these have (to a greater or lesser extent) a high-pitched "beeping" sound toward the high-frequency end of audibility. This is mainly in the few pre-September 1997 recordings on Disc One (tracks 21 - 25), and only a few of them are heard because all the tracks on Disc One (from source cassette tapes) were recorded into digital files (with 22050 Hz/16-bit sampling rate) that do not any allow for audio frequencies above 11 kHz. I should note here that Disc Two was sampled at full-CD quality at 44100 Hz, allowing for sounds up to 22 kHz to be reproduced, as all the tracks on Disc Two were recorded digitally. However, there are no Omega transmissions audible on any of the Disc Two VLF tracks.

The beeping sounds are transmissions of the worldwide (and now defunct) **Omega Radionavigation System** run jointly by the U.S. Coast Guard and other partner countries military departments concerned with navigation.

Omega is now off-the-air since 30 September 1997 thanks to the advanced GPS (Global Positioning System) satellite navigation system. Omega previously consisted of eight 10,000 watt transmitters in the following locations: Australia (Victoria), Japan; Hawaii (Oahu) near Kailua; North Dakota (USA) near La Moure; Liberia (Africa); La Reunion Island; Argentina; and Norway. Each transmitter transmitted eight "pulses" of 0.8 to 1.2 seconds duration, repeating the process every 10 seconds. During each cycle, each transmitter occupied a unique frequency, and over the course of each 10 second cycle, all of the eight transmitters "hit" on several common frequencies spanning 10.2 to 13.8 kHz.

Also, each transmitter transmitted on its own "unique" frequency on 2 of its 8 transmitted pulses. Omega receivers used to sample the relative phase and timing of each Omega signal. Best results were obtained when at least 4 Omega transmitters were received and analyzed, and the nearest resolution, called a "lane" is about 5-6 miles (8-10 km) wide. Omega was subject to the same VLF propagation disturbances which affect Natural Radio, particularly during magnetic storms. When dawn chorus fills the receiver headphones, Omega is probably experiencing accuracy problems!

There were also daily (diurnal) variations in the accuracy and phase of the Omega signals as day becomes night, which for the most part were taken into account within an Omega receiver's internal microprocessor. GPS, at microwave frequencies, does not suffer any of these particular propagation errors as does Omega.

As such, Omega is no longer on the air, though Russia (not wishing to be totally reliant upon GPS) still operates a smaller-scale version of Omega called **"Alpha."** Alpha has only three (possibly four) transmitters sending three short pulses of approximately 100 milliseconds in duration, followed by a pause of a couple seconds' duration. In North America, Alpha is considerably weaker in strength than Omega was, particularly for listeners previously within a thousand miles of an Omega transmitter.

The one thing natural VLF experimenters and listeners miss about Omega was that the beeps of Omega could be used to synchronize recordings and to align spectrograms, and they made for an excellent, highly accurate time-base in such recordings.

Military (MSK-mode) stations: There are many military communications stations transmitting encrypted MSK data, usually intended for submarine communication. They operate just above the audio-frequency band where natural VLF emissions are audible, in the 19 to 30 kHz region. While normally not audible in the passband of a receiver made to receive natural VLF emissions (such as the two used to record this album), they can cause distortion products in its audio-amplification circuitry, resulting in an odd pulsing tone of various frequencies. This appears in a couple tracks on Disc One (in recordings made at the northern Alberta VLF site in August 2000), most notably Tracks 7 and 13 of Disc One. The right-channel loop was pointing in a direction most sensitive in an east-west direction, and it was receiving a fairly close-by MSK signal that either was not on the air continuously, or propagation varied its signal enough to reach an occasional threshold where it overloaded the loop antenna preamplifier circuitry.

Power line "hum" from alternating current electric wires: Switch on a VLF receiver within your home or office, and you will not hear anything BUT this sound! Today, all electricity generated at power plants is "alternating-current (AC)," as opposed to "direct-current (DC)" produced from batteries in your watch and portable radios. With AC, the polarity changes a many times a second. In Europe, Asia, most of Africa, and Australia/New Zealand, the electric mains power changes polarity 50 cycles-per-second, or 50 Hz. In North America and in most (but not all) Central and South American countries, it is at 60 Hz.

While necessary for long- distance transmission and voltage transformation, AC generates hum in poorly filtered audio equipment and especially in sensitive natural VLF radio phenomena receivers. If this wasn't bad enough, most electrical "grids" seem to cause the 50 of 60 Hz current to generate harmonics--multiples of 50 of 60 Hz, causing hum/buzz THROUGHOUT the VLF radio spectrum. Those immense, high-voltage, high-tension electric wires sagging between the tall metal pylons and marching off toward the horizon can generate impossible amounts of hum and buzz if you try to listen with a VLF receiver too close to them-and I'm talking about miles near to them! My own sensitive receivers have picked up the hum sounds from powerlines located as much as 25 miles away, where no others were closer. In Tracks 21 through 24, whistler recordings made in northern Nevada in April 1996, there is noticeable powerline hum in the background. The location where these recordings were made was only about 5 from two large sets of powerlines to the north AND south of the recording site.

To obtain quality, "hum-less" recordings of VLF phenomena (as in most of the other tracks on both these two CD's), a listening/recording site far removed from above-ground power lines must be found. It's fairly easy to find absolutely quiet hum-free listening spots in desert, mountainous/alpine or tundra regions of western North America, Australia, or the remoter (i.e. northern) parts of Europe and the British Isles (Scottish Highlands particularly), but finding quiet spots to listen close to home and/or in populated regions with many towns near each other, or in farmed regions, usually mean pesky power lines will be around somewhere, likely alongside the road being traveled.

Willingness to walk/hike into listening sites greatly increases the chances that a quiet spot will be found. In most cases, a bit of background hum is going to be the situation and can be tolerated. Surprisingly, reasonably low-hum natural VLF radio listening spots (low enough to allow for audibility of most of the louder VLF emissions) can be found in places such as large ball fields, large urban/suburban parks away from light poles and/or where lines are buried, farm fields where wires low-voltage lines are hidden behind trees (or are placed underground), along many beaches (especially if electric wires are below-ground), and so forth. It has been found that within southwest London's Richmond Park and Battersea Park, quite a few remarkably low-hum listening spots exist. This is also true for San Francisco's Golden Gate Park's soccer/football playing fields. Low hum does not mean NO hum, and so for absolutely quiet, hum-free recordings to be made, careful selection of regions and specific areas within those regions is necessary -- i.e., heading into the remote boondocks and roughing it!

About the Spectrograms: The spectrograms presented in this document were produced with GRAM42 from contents in these two CD's re-recorded into 22050 Hz sampled files and then analyzed with Gram42. The output spectrograms were then saved as bitmap images and imported into the application used to write this paper. An MP3 file in the data section of Disc Two: **examples.mp3** contains the five audio segments used to make the spectrograms, in the order of which the spectrograms appear on these pages.

About Stereo Recording, Antenna Directionality, and VLF emission sources: Both of the wire loop antennas used to make all of the stereo tracks and a couple of the mono tracks on both of these two CD's were hung vertically in trees. They are roughly triangular in shape, and each loops have two "nulls" and "peaks" in sensitivity along a horizontal azimuth. Directions along planes of the loops are the "peaks" and directions 90-degrees to the loop plane are the "nulls." This is known as "bi-directionality" and is best taken advantage of when one loop antenna is oriented 90 degrees difference in horizontal azimuth direction from the other loop.

In the case of the August 2000 expedition to Alberta, the right channel was recorded from a (black) loop oriented for maximum sensitivity in an east/west direction, and the left-channel (red) loop was oriented for maximum sensitivity of pickup in a north-south direction. (The colors of the loops refer to the color of their wire insulation seen in photographs in an accompanying PDF document on CD Two - see the file: Auroral_Chorus_III_Guide.pdf).

In Saskatchewan, the right-channel loop (red) was oriented for maximum sensitivity in a northwest/southeast direction, and the left-channel loop (black) was oriented for maximum sensitivity in a northeast/southwest direction.

Nearly all of the lightning static (sferics) signals arrive to the antennas along the horizon - propagating as do most other terrestrial-origin radio signals along the surface of the Earth. As such, directionality of lightning static is very noticeable in the stereo recordings. Listening carefully to the differences between the right and left channels, you may have noticed that directionality of other VLF signals, such as chorus and whistlers, varies a bit from CD track to track, but not as noticeably as with lightning sferics. This is because most of the natural VLF radio emissions are arriving to my recording locations not from away toward the horizon but from ABOVE - the signals have been propagated (from their sources farther out in space) along Earth's magnetic-field lines, and actually arrive along the lines of the magnetic field.

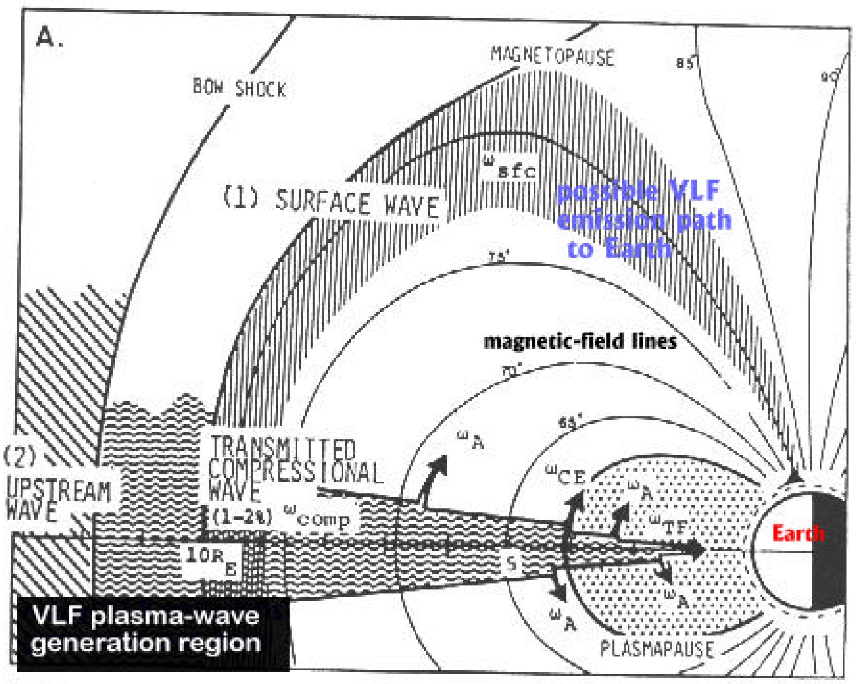
Earth's magnetic-field lines - in a roughly dipolar pattern, intersect Earth's surface in the auroral-zone from a nearly vertical direction - actually, between 65 and 75 degrees from horizontal, and they tilt toward the south. This is also known as the magnetic "dip angle." Photographs of aurora clearly show the lines of Earth magnetic-field, seen as "rays" or "pillars" or other near-vertical lines in the auroral forms (also refer to diagram further below). Notice the field-aligned pattern in the auroral photo (CD cover photo) on page 1 of this document - this photograph was taken looking toward the east, and show the field-lines tilting toward the south.

The above photo shows a display early the morning of 10 August 2000 in northern Alberta looking toward the west - notice the tilting lines (magnetic field) in this photo are sloping in the opposite way from the CD cover photo on Page One.

Aurora of 31 March 2001 - midnight PST - southern Owens Valley, California - S. McGreevy

Photos of aurora taken in more southerly locations below latitude 40 (in North America) show increasing dip-angle "tilt" in the field-aligned rays and pillars. Aurora seen from such southerly latitudes tends to be seen mostly toward the north, and so the greater magnetic-dip-angle tilt southward is not as obvious, such as is the case with the above photo (31 March 2001, looking north/northeast) of aurora high in the sky over Inyo County in eastern California. There was a very brief moment when the aurora seen in this photo reached zenith overhead and even farther south, and it appeared to actually “lean” over at an angle of about 55 degrees from horizontal when I looked toward the east or west!

Many natural VLF radio emissions such as chorus, risers, hooks, hissband, etc., are generated out in space (several Earth-diameters distant from Earth’s surface) along the equatorial plane within Earth’s magnetic-field (magnetosphere). They originate as waves within the magnetosphere’s plasma (hot gases and electrified particles) where the sun’s solar wind impacts the magnetosphere. Many signals then follow along Earth’s magnetic field, arriving along a magnetic line-of force shown in the picture below, becoming conventional radio (electro-magnetic) waves below the plasma-pause. These lines-of-force are clearly seen in auroral photographs shown above and indicated with the red line.



The diagram above (from AGU Monograph 53, pg. 201 - Kuwashima and Fujita, with additional labels added by McGreevy) shows the daylight-side of the magnetosphere and how VLF plasma-waves generated out in space travel to Earth’s surface where they are heard as VLF radio signals. Since both loop antennas feeding the right and left-channel receivers are sensitive to signals coming from above due to being erected as vertically-hanging triangles (deltas), they tend to show less directionality to most natural VLF signals except from lightning static.

It is possible for many natural VLF signals arriving along a magnetic-field line-of-force to then propagate along Earth’s horizon for many hundreds of miles (as standard, terrestrial-origin radio signals do). These now horizontally-traveling VLF signals then can be stronger in one loop antenna versus the other, depending upon the horizontal azimuth direction they arrive to the antenna. These signals are the ones which differ most greatly between the left and right channel loop antennas.

In conclusion, many natural VLF radio signals are arriving from near space, originating many thousands of miles distant and several Earth-diameter distances away. Enjoy the beautiful sounds of natural radio!

S. P. McGreevy, September 2001 - www.auroralchorus.com

Signature Not Verified

Stephen P. McGreevy

Digitally signed by Stephen P. McGreevy
DN: cn=Stephen P. McGreevy, o=S. P. McGreevy Productions, c=US
Date: 2001.09.18 11:10:01 -08'00'