
Electric Enigma

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Few people know of and even less people have been fortunate enough or had the gumption to tune into the beautiful radio "music" produced naturally by several processes of nature including lightning storms and aurora, aided by events occurring on the Sun. I have been fascinated with listening to naturally-occurring radio signals since about the middle of 1989, hearing my first whistlers almost immediately after first trying out a rudimentary receiving apparatus I had put together for the occasion. Whistlers, one of the more frequent natural radio emissions to be heard, are just one of many natural radio "sounds" the Earth produces at all times in one form or another, and these signals have caught the interest and fascination of a small but growing number of hobby listeners and professional researchers for the past four decades.

"Natural Radio", a term coined in the late 1980's by California amateur listener and researcher Michael Mideke, describes naturally-occurring electromagnetic (radio) signals emanating from lightning storms, aurora (The Northern and Southern Lights), and Earth's magnetic-field (the magnetosphere). The majority of Earth's natural radio emissions occur in the extremely-low-frequency and very-low-frequency (ELF/VLF) radio spectrum specifically, at AUDIO frequencies between approximately 100 to 10,000 cycles-per second (0.110 kHz). Unlike sound waves which are vibrations of air molecules that our ears are sensitive to, natural radio waves are vibrations of electric and magnetic energy (radio waves) which though occurring at the same frequencies as sound cannot be listened to without a fairly simple radio receiver to convert the natural radio signals directly into sound.

Whistlers are magnificent sounding bursts of ELF/VLF radio energy initiated by lightning strikes which "fall" in pitch. A whistler, as heard in the audio output from a VLF "whistler receiver", generally falls lower in pitch, from as high as the middle-to-upper frequency range of our hearing downward to a low pitch of a couple hundred cycles-per-second (Hz). Measured in frequency terms, a whistler can begin at over 10,000 Hz and fall to less than 200 Hz, though the majority are heard from 6,000 down to 500 Hz. Whistlers can tell scientists a great deal of the space environment between the Sun and the Earth and also about Earth's magnetosphere.

The causes of whistlers are generally well known today though not yet completely understood. What is clear is that whistlers owe their existence to lightning storms. Lightning stroke energy happens at all electromagnetic frequencies simultaneously that is, from "DC to Light". Indeed, the Earth is literally bathed in lightning-stroke radio energy from an estimated 1,500 to 2,000 lightning storms in progress at any given time, triggering over a million lightning strikes daily. The total energy output of lightning storms far exceeds the combined power output of all man-made radio signals and electric power generated from power plants. Whistlers also owe their existence to Earth's magnetic field (magnetosphere), which surrounds the planet like an enormous glove, and also to the Sun. Streaming from the Sun is the Solar Wind, which consists of energy and charged particles, called ions. And so, the combination of the Sun's Solar Wind, the Earth's magnetic field surrounding the entire Planet (magnetosphere), and lightning storms all interact to create the intriguing sounds of whistlers.

How whistlers happen from this combination of natural solar-terrestrial forces is (briefly) as follows: Some of the radio energy bursts from lightning strokes travel into space beyond Earth's ionosphere layers and into the magnetosphere, where they follow approximately the lines-of-force of the Earth's magnetic field to the opposite polar hemisphere along "ducts" formed by ions streaming toward Earth from the Sun's Solar Wind. Solar Wind ions get trapped in and aligned with Earth's magnetic field. As the lightning energy travels along a field-aligned duct, its radio frequencies become spread out (dispersed) in a similar fashion to light shining into a glass prism. The higher radio frequencies arrive before the lower frequencies, resulting in a downward falling tone of varying purity.

In this manner, a whistler will be heard many thousands of miles from its initiating lightning stroke and in the opposite polar hemisphere! Lightning storms in British Columbia and Alaska may produce whistlers that are heard in New Zealand. Likewise, lightning storms in eastern North America may produce whistlers that are heard in southern Argentina or even Antarctica. Even more remarkably, whistler energy can also be "bounced back" through the magnetosphere near or not-so-near the lightning storm from which it was born! There will be additional discussion of this "theory of whistlers" in the next few pages.

Considered my many listeners to be the "Music of Earth", whistlers are amongst the accidental discoveries of science. In the late 19th century, European long-distance telegraph and telephone operators were the first people to hear whistlers. The long telegraph wires often picked up the snapping and crackling of lightning storms, which was mixed with the Morse code "buzzes" or voice audio from the sending station. Sometimes, the telephone operators also heard strange whistling tones in the background. They were attributed to problems in the wires and connections of the telegraph system and disregarded. The first written report of this phenomenon dates back to 1886 in Austria, when whistlers were heard on a 22-km (14 mile) telephone wire without amplification. A paper by W.H. Preece (1894) appearing in Nature Magazine describes operators at the British Government Post Office who listened to telephone receivers connected to telegraph wires during a display of aurora borealis on March 30 & 31, 1894. Their descriptions suggest they heard whistlers and the "bubbling/murmuring" sounds of "Chorus" from aurora.

During World War I, the Germans and Allied forces both employed sensitive audio-amplifiers to eavesdrop on the enemy's telephone communications. Metal stakes were driven into the ground next to enemy telephone wires and were connected to tube-type high-gain amplifiers, whereby the audio signal in the telephone wires could be eavesdropped. This early form of electronic espionage worked fairly well most of the time, despite the bubbling and crackling background noise made by lightning but not always. On some days, the telephone conversations they were eavesdropping on were partially or wholly drowned out by strange whistling sounds. Soldiers at the front would say, "you can hear the grenades fly". These whistling sounds, described as sounding almost like "piou", were at first attributed to the audio amplifiers' circuitry reacting adversely to strong lightning discharge noises. When laboratory tests on the high-gain audio amplifiers failed to recreate the whistling sounds, the phenomena was then considered "unexplainable" at that time. (H. Barkhausen, 1919).

In 1925, T. S. Eckersly of the Marconi Wireless Telegraph Company in England, described disturbances of a musical nature that had been known to "radio" engineers for many years. They were heard when a telephone or any other "audio-recorder" system was connected to a large aerial. What they were hearing are now known as "tweeks", a common ringing and pinging sound that lightning discharge radio energy (sferics) atmospherics sound like at night with a VLF receiver or audio amplifier. Several people began to observe how lightning and auroral displays coincided with many of the strange sounds they were hearing with their audio apparatus (Barkhausen, Burton, Boardman, Eckersly, et al.). In the 1930's, the relationship of whistlers and lightning discharges was hypothesized, and in 1935, Eckersly arrived at the commonly accepted explanation that lightning initiated radio waves traveling into Earth's "ionosphere" caused these tweek sounds. They were getting "close".

Interest in whistlers waned during World War II but was renewed with the development of sound spectrographs and spectrum analyzers, which could trace the time-versus-frequency component of audio sounds. This technology was developed mainly for the study of the sound characteristics of speech and other sounds, but these also were fine tools for the exploration of whistlers, as well (R. K. Potter, 1951).

It was during this time that L.R.O. Story in Cambridge, England, had begun an in-depth investigation into the nature and origin of whistlers. Armed with information presented by Barkhausen, Boardman, et al., a homemade spectrum analyzer and other audio-frequency radio equipment, Storey studied whistlers in earnest, discovering several types of whistlers that were or were not audibly associated with lightning discharge "clicks" in the receiver. He was able to make graphs of many kinds of whistlers, forming the basis of the modern "magneto-ionic" theory of their origin, and also the effects of Earth's magnetic storms on whistlers.

Storey's conclusion that whistlers were formed by lightning discharge energy echoing back and forth along the lines-of-force of earth's magnetic field suggested that there was a much higher than expected ion density in the outer ionosphere and beyond, and that the source of this "extra" ionization was linked to the sun. He also (correctly) presumed these ions from the sun also were responsible for magnetic storms and auroral displays.

Storey, while mainly concentrating on whistlers, was able to hear and categorize a number of other audio-frequency emissions that he heard, including Dawn Chorus, steady hiss, and certain "rising whistlers", also known as "risers". Story's studies throughout the early-to-mid 1950's made an important contribution to whistler theory by showing that whistlers travel very nearly in the direction of Earth's magnetic field. In 1952, the results of Storey's work were presented by J. A. Radcliffe to the Tenth General Assembly of the URSI held in Sydney Australia, exciting considerable interest among the delegates in attendance. Radcliffe's report greatly stimulated whistler research at Stanford University, headed by the "Father of Whistler Research", R. A. Helliwell.

In 1954 at the next URSI General Assembly held in the Hague (Netherlands), whistler theory was discussed in depth, and plans were devised to study whistlers at opposite "conjugate" points of Earth's magnetic field. Lightning storm atmospherics observed in one hemisphere were heard as "short whistlers" (1-hop whistlers) in the opposite hemisphere. This notable observation was conducted by Helliwell at Stanford in California and aboard the U.S.S. Atka located in the South Pacific near the opposite magnetic conjugate point. Lightning storms generating atmospheric static "pops" as heard in the ship's onboard VLF receivers were heard nearly simultaneously in Stanford as short whistlers. Even more verification of Storey's whistler was confirmed by the observation of whistler "echo trains" simultaneously heard in Alaska and in Wellington, New Zealand, which lies at the opposite magnetic conjugate from Alaska.

With this generalized history of whistler discovery and research in mind, I should pause this history lesson and now explain whistler theory in somewhat greater detail. The generally accepted theory of whistlers (Storey, Morgan, Helliwell) is as follows (the following few paragraphs are taken directly from the text of my WR-3 "Whistler Receiver" Listening Guide and repeat some information presented earlier in this article as well as hopefully making clearer some terms I've been tossing about):

The Earth's outer magnetic field (the "magnetosphere") envelopes the Earth in an elongated doughnut shape with its "hole" at the north and south magnetic poles. The magnetosphere is compressed on the side facing the Sun and trails into a comet-like "tail" on the side away from the Sun because of the "Solar Wind" which consists of energy and particles emitted from the Sun and "blown" toward Earth and the other planets via the Solar Wind. Earth's magnetosphere catches harmful electrically charged particles and cosmic rays from the Sun and protects life on Earth's surface from this lethal radiation. Among the charged particles caught in the magnetosphere are ions (electrically charged particles), which collect and align along the magnetic field "lines" stretching between the north and south magnetic poles. These magnetic-field aligned ions bombarding Earth's magnetosphere form "ducts" which can channel lightning-stroke electromagnetic impulse energy. Whistlers result when an electromagnetic impulse (sferic) from a lightning-stroke enters into one of these ion-ducts formed along the magnetic lines of force, and is arced out into space and then to the far-end of the magneto-ionic duct channel in the opposite hemisphere (called the opposite "magnetic conjugate"), where it is heard as a quick falling/descending emission of pure note tone or maybe as a brief "swish" sound. Whistlers sound the way they do because the higher frequencies of the lightning-stroke radio energy travel faster in the duct and thus arrive before the lower frequencies in a process researchers call "dispersion". A person listening with a VLF receiver like the WR-3 in the opposite hemisphere to the lightning stroke (at the far end of the Magnetospheric duct path) will hear this "short" or "1-hop" falling note whistler. One-hop whistlers are generally about 1/3 of a second to 1 second in duration. If the energy of the initial short/1-hop whistler gets reflected back into the magneto-ionic duct to return near the point of the originating lightning impulse, a listener there with a VLF receiver will hear a "pop" from the lighting stroke impulse, then roughly 1 to 2 seconds later, the falling note sound of a whistler, now called a "long" or "2-hop" whistler. Two-hop whistlers are generally about 1-4 seconds in duration depending on the distance the whistler energy has traveled within the magnetosphere. One-hop whistlers are usually higher pitched than two-hop whistlers. The energy of the originating lightning stroke may make several "hops" back and forth between the northern and southern hemispheres during its travel along the Earth's magnetic field lines-of-force in the magnetosphere. Researchers of whistlers have also observed that the magnetosphere seems to amplify and sustain the initial lightning impulse energy, enabling such "multi-hop" whistlers to occur, creating long "echo trains" in the receiver output which sound spectacular! Each echo is proportionally longer and slower in its downward sweeping pitch and is also progressively weaker. Conditions in the magnetosphere must be favorable for multi-hop whistler echoes to be heard. Using special receiving equipment and spectrographs, whistler researchers have documented over 100 echoes from particularly strong whistlers—imagine how much distance the energy from the 100th echo has traveled—certainly millions of miles! Generally, only one to two echoes are heard if they are occurring, but under exceptional conditions, long "trains" of echoes will blend into a collage of slowly descending notes and can even merge into coherent tones on a single frequency, hard to describe here, but quite unlike any familiar sounds usually heard outside of a science-fiction movie!

Back to the history of whistler research. Plans for studying whistlers, chorus, and other audio-frequency natural radio phenomena were formulated by Dr. J. G. Morgan of the University of New Hampshire in Hanover as well as Dr. Helliwell at Stanford, for the International Geophysical Year which would begin in 1957. Over 50 receiving stations were set up at many locations all over the globe, including remote locations in northern Canada, Alaska, Europe including Scandinavia, and even Antarctica. This period was the beginning of the most intensive professional study of whistlers ever. In the early 1960's, a couple of satellites (IEEE-1, Injun, Allouette) destined for low Earth Orbit were outfitted with VLF receivers. These satellite-based VLF radio receivers successfully recorded whistlers, and greatly enhanced scientific knowledge of natural VLF radio emissions. During the 1970's, space probes, such as Pioneer and Voyager, would discover whistlers happening on other planets of our Solar System, such as Jupiter and Saturn, which both have enormous and powerful magnetospheres. These Gas Giants also have huge magnetospheres and their own polar aurora as well.

The 1980's saw increasing hobbyist and amateur observations of whistlers, thanks to the increasingly easy availability of solid-state electronic parts and VLF receiver construction articles and notes. By 1985, whistler articles and receiver designs would appear in several electronic and radio hobbyist magazines, and also radio club bulletins most notably the Longwave Club of America's monthly bulletin, THE LOWDOWN. Several LWCA members including Michael Mideke, Mitchell Lee, Ev Pascal, Ken Cornell, and others, would publish and or design and use their own successful whistler receiver versions. These hobbyist whistler receivers tended to use small loop or wire antennas, unlike the "professional" VLF receivers used during the late 50's and early 1960's, which used very large loop and/or tall vertical "pole" antennas.

One radio "mentor" who sparked my fascination with whistlers and Natural Radio is a gentleman named Michael Mideke, who has been an avid enthusiast involved in various esoteric radio (and non-radio) pursuits since the early 1970's. Mike taught me quite a considerable amount of knowledge about longwave radio receiving and transmitting experimentation at radio frequencies much higher than Natural Radio, and he himself began regularly monitoring Natural Radio about the middle of 1988, more than a year before I would hear my first whistler in the Oregon desert. For the past 25 years, Mike, his wife Elea, and two sons lived as caretakers on a large ranch in a remote central

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California canyon, far from electric powerlines. Here, Mike was able to string out antenna wires over thousands of feet in length and running in several different compass directions, and connect them to his plethora of radio receivers. His remote, electrically-quiet location was also ideal for listening to whistlers. Over the years, Mike has also made many hundreds of hours of recordings of amazing radio sounds of the Earth. He was particularly fortunate to be able to monitor 24 hours a day during the height of the sunspot cycle from 1989-1991 when solar activity, geomagnetic disturbances, and whistlers were most numerous. Mike also passed along the results of his own receiver experimentation, thus positively influencing my own receiver experimentation.

In late summer of 1990, I began experimenting with whistler receivers employing short "whip" antennas no longer than 5 to 6 feet in length. These "whip receivers" successfully monitored whistler activity, though my earliest versions lacked sensitivity. I must credit the original idea of using a short whip antenna to a longtime close friend and fellow whistler enthusiast, Gail West, who lives in Santa Rosa, California and has accompanied me on many of my road trips and whistler listening expeditions. Gail repeatedly witnessed my frustration with stringing out unwieldy wire antennas, and on one particular morning (summer 1989) in the northern Nevada desert, commented "it sure would be nice to use just a small whip antenna rather than long wires for a whistler receiver antenna". Also, while on a solo listening session in the hills of Marin County, California in February 1990, I heard a strong whistler howl from the tape recorder's speaker with nearly all but about 10 feet of antenna wire rolled back onto the spool. This experience reminded me of Gail's idea and made the whip antenna idea seem more plausible. While the idea of a hand-held whistler receiver seemed somewhat wishful thinking early on in my experimentation with whistler receivers, it would become reality in just over two years of whistler listening and receiver tinkering.

Increasingly better and more sensitive yet simpler whip antenna whistler receivers were continuously devised on my workbench. On a beautiful spring morning in May 1991 while hiking on a trail in the mountains east of San Diego with friend Frank Cathell of Conversion Research, I demonstrated my BBB-2 whip antenna whistler receiver. Frank was so fascinated with this receiver that he jumped on the bandwagon, and by August 1991 after a furious 3 months' of receiver tinkering, Frank and I created a sensitive battery-powered whistler receiver that required only a small 33-inch antenna, was cigarette pack sized and very portable, called the "WR-3", and we shortly began selling this new pocket receiver on a casual basis. The WR-3 opened up whistler monitoring to practically everyone-even non-technical people willing to at least undertake the effort of finding a reasonably powerline "hum" free location where whistlers and other natural VLF radio phenomena could then be listened to and enjoyed as easily as listening to regular broadcast radio. At this point thanks to the WR-3, whistlers and lightning sferics were very easy to hear now it was just up to Mother Nature to put on a show.

My difficulties with whistler receivers and antennas was now behind me, but I still retain very fond memories of the beginnings of my own interest in whistler listening and study. In June 1989, Gail and I heard our first whistlers "live" while camped deep in the eastern Oregon desert near Steens Mountain. In anticipation of the trip and not yet aware of more advanced receiver circuits available for this pursuit, I built a crude "whistler-filter" which I knew would at least block out a lot of the potential man-made signals which might overload my tape-recorder's audio-amplifier. During the days leading up to desert trip, Summer thunderstorms had been plaguing the Great Basin areas of central and northern Nevada the result of the typical summertime "monsoonal" moisture which sometimes gets driven up northward from the southwestern states of Arizona and New Mexico toward the inter-mountain region of the western U.S. (including Utah and Nevada). July and August are the months of the most spectacular lightning storm displays that pound almost daily throughout the deserts and mountains of western North America.

As Gail and I arrived at our intended campsite in the Black Rock Desert of northern Nevada, one of the more fiercer-looking cumulonimbus clouds drifted in our direction, and a light rain began to patter the parched desert dirt. Shortly thereafter, the wind picked up accompanied by the rumble of thunder. It looked like we were going to be in for quite a bit of this judging by the looks of the clouds. As we tried to set up our "Tahjmatent" a huge dome tent which was tall enough to stand up in and roomy enough for 10 people to sleep in the winds started to blow so hard all Gail and I could do was just stand there holding the now horizontally flailing tent. The situation seemed rather dismal, however the skies to the north looked almost cloud-free, so we decided to cram our big wad of a tent and other supplies back into my small Toyota coupe and head farther north to an alternate location in Oregon about 100 miles away. We would return to the Black Rock Desert the following month under clear skies.

Arriving in the Alvord Desert of south-eastern Oregon with about 1½ hours of sunlight left, we set up the tent under clear blue skies while occasionally stealing glances at the still ominous-looking skies to the distant south, hoping it would not come up our way. Fortunately, we were spared any further harassment from the weather and I became confident I could unroll my nearly 500 meter-long wire across the sagebrush. I connected my whistler filter to this wire and "grounded" the other connection to the car. Connecting my tape-recorder to the filter, I was rewarded by loud snapping and crackling from all the lighting happening south of us.

The following morning at sunrise under cloudless skies, I turned on the tape-recorder and listened to the now greatly reduced amount of lightning static. But, a few of the louder lightning "pops" had whistlers (or what I thought sounded like "whizzers") happening a second or two afterward! I shouted for joy and thrust the headphones at Gail for her to listen, too. We were hearing our first whistlers, though they sounded different from the few I had heard recorded on cassette tape by Michael Mideke back in central California. The whistlers went on for an hour or so then died away. The following morning, the whistlers were back, but even louder! An already very enjoyable desert trip had turned into a milestone for me!

Now that I had heard whistlers on my own, I became "hooked" with this very esoteric aspect of radio listening. I had been enjoying shortwave listening to stations around the world and amateur "ham" radio for the past dozen years, but this was something very new and fascinating something that played well into my other casual and hobby interests in geophysics, meteorology, and radio wave propagation studies.

Over the next few years, I would learn a great deal about natural radio phenomena and how to build excellent receiving equipment to listen for whistlers and the like. One of the main goals was to build a whistler receiver that would not require a whole roll of antenna wire but only a small whip antenna desire which came to fruition in the spring of 1990, when I "accidentally" heard a loud whistler while rolling up the final few meters of antenna wire. I knew it was possible to hear whistlers with small antennas, and as I've already mentioned, a prototype to my portable hand-held "WR-3" receiver was devised a in the spring of 1991 with the help of another radio friend, Frank Cathell of Conversion Research.

In addition to all of my whistler receiver tinkering, trials and successes mentioned above, serious and regular natural radio listening (and quality

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recordings) began in February 1991, when nearly every Sunday morning well before sunrise (the "prime time" to listen for whistlers), I would pack my favorite whistler receiver, a small reel-to-reel tape recorder, and lunch into a knap sack and bicycle to the nearby hills. Upon reaching the base of the hills, I would then dismount and walk the bike up via a fire access-road to my favorite listening spot a flat ridgeline overlooking much of Marin County, San Francisco, and San Pablo Bay at an elevation of about 600 feet above sea-level which I began calling "Whistler Hill". Here, I would listen for whistlers, and if there were any happening, run the tape recorder. I was rewarded by many beautiful sunrises and many nice whistlers on my weekly visits to Whistler Hill, and I was quite happy with my current receiver, a unit which used a 66-inch whip antenna, called the "MC-1". One memorable morning near Easter 1991, a "huge" whistler the loudest of the morning occurred just as the sun began peeking above the north-northeastern horizon. It was in this year that I would really discover the aesthetic beauty of whistler listening while out in nature!

While I was always glad to hear whistlers in the hills, it was not always easy to awake at 4 a.m. in the cold and bicycle the few miles up to Whistler Hill. Many of those Sunday mornings would have been better spent sleeping a few hours longer, but Oh!, was I so glad when those whistlers would be pouring forth in my receiver's headphones as another gorgeous sunrise was forthcoming then I was always glad I made the effort to get up early! But then again, I would sometimes get up to Whistler Hill only to hear NOTHING except the everpresent crackling of Earth's ongoing electrical storm commotion. And if the weather was gloomy, I was usually tempted to ride back home instead of continuing on my usual 8-10 mile bike and hike.

Why DIDN'T I stay home and listen to whistlers from the comfort of my bed, as is generally possible with more conventional broadcast radio? The problem lies with the electric-mains grid which has spread nearly every place man has settled. Alternating-current electric power lines emit "hum" at 60 cycles-per-second in the Americas, and 50 c.p.s. (Hz) in Europe and Asia. In addition to these "fundamental" AC power frequencies, "harmonic" energy is also radiated (120, 180, 240, 300, 360 Hz, etc.), or as in Europe and Asia: 100, 150, 200, 250, 300 Hz, etc.) often to well above 1 or 2 kHz. Since whistler receivers are sensitive to these electric power frequencies, any natural radio events which might be occurring get masked by this terribly annoying humming sound, should one try to listen anywhere near AC powerlines.

The only solution to AC power-line "hum" is to locate a listening spot away from AC power poles and wires often as far as several miles before the hum levels are reduced to low or nil levels. This necessitates walking, hiking, bicycling, or driving to remote locations where there are few or no AC power lines easy to do in many parts of California and the West but often very difficult in flat land or urban locales. Sometimes and with good filters in the whistler receiver one can listen as close as a couple-hundred feet (or maybe even closer) to residential AC electric wires. On a few fortunate and astounding occasions, whistlers can get so loud as to even be heard through the loud power-line hum levels encountered in a suburban backyard, demanding the whistler listener to immediately relocate to their favorite "quiet" listening spot in order to hear and tape record such magnificently giant whistlers, and at the same time praying that the monster whistlers still are going on when the whistler receiver is again turned on! Murphy's Law and my experiences generally suggest they will be gone and not to return until another inopportune time...

My tape libraries of whistlers and other natural radio phenomena vastly increased in late 1992 and throughout 1993 and early 1994. The stimulus to get out and make natural radio recordings came when, after purchasing a "camper-van" in July 1992, Gail and I headed up California's North Coast, stopping for the night at Westport Union Landing Beach north of Fort Bragg. We heard nice whistlers that evening and morning during darkness using our WR-3's clamped in the van's rear doors while laying in our comfy beds. Occasionally, however, one or both WR-3's would slip out of the door and nearly hit our heads. Gail came up with an idea to have a whistler receiver with an antenna that could remain outside while a control box could be put next to the beds. Well, I got right to work on this great idea of hers upon returning home, and quickly designed an excellent "WR-4" whistler receiver in which the receiving antenna (2.5 meters in length) is mounted on the van's read door ladder and the control-box containing filter switches, headphone and tape-recorder jacks, etc. could be placed next to the bed! Now, I could make recordings while comfortably in bed, even while dozing off letting the recorder run for 45 minutes or until I awoke to monitor the situation. Since recording became very "convenient" while camping no more sore arms holding the receiver out the window or standing out in the cold and win, and not as much sleep deprivation as before I (alone or with Gail) am now able to locate to superbly quiet camping/listening locations deep in the desert or near mountainous areas and wait for conditions to present interesting natural radio sounds. The past couple of years has seen the combining of my enjoyment of camping and road trips with natural radio listening.

The ease of whistler listening with the WR-4 and our love or camping trips has resulted in about a hundred hours of recording in 1993 and 1994 from over 10,000 miles of travel a natural radio tape library which has become one of the better ones from an amateur, but I have no doubt that Mike Mideke's has to clearly be the FINEST amateur/hobby tape library in the world, since he LIVED in a quiet location free from strong powerline "hum" and has not had to travel to enjoy natural radio.

When Donald Cyr initially inquired if I would like to contribute some thoughts on whistler listening and experiences during the past couple of years since I last contributed material to his book: America's First Crop Circle; Crop Circle Secrets Part 2, I said "sure, I'd love to write something for your new book". Don was interested in any information I might be able to offer, such as where the best places to hear whistlers are, or if I found any particular places that whistlers were consistently stronger than in other locations. I assume he was hopeful that my findings might tie in to his theory, which I'll call "The Marion Island-Wiltshire Plain Crop Circle Theory", (a name I have created for this article) that suggests whistlers at least the ones which might have caused many English Crop Circles in the late 1980's and early 1990's-are highly localized phenomena that are launched at a given point, such as Marion Island in the south Atlantic Ocean, and are ducted via the magnetosphere along a line-of-force to the northern hemisphere, specifically, to southern England, where they, if they do not cause odd impressions in wheat fields of the Wiltshire Plain, will nonetheless be very LOUD indeed to one listening for them with a whistler receiver.

Don's theory, backed by his friend and colleague James Brett, was first presented to his readers in CROP CIRCLE SECRETS, PART 1, published in 1991 and highly recommended reading for this discussion as is PART 2, published in 1992. This particular book of Don's generated a good deal of interesting dialogue, and discussion. Of course, Don and James's Crop Circle Theory was really aimed at stimulating query and discussion about the what the mysterious forces which might be creating such incredible and beautiful impressions in the English landscape and that is the true driving force of inquiry and research. Other theories were pondered, suggested, debated, and dismissed by various contributors to Don's books, and they ranged from elaborate UFO theories, vortices and balls of light, military exercises (there are several military installations in that English region), underground forces of electromagnetic nature, to suppositions that they were plain and simply, artistic hoaxes

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concocted in the night by creative people armed with poles and chains.

Don and James were fascinated by the whistler theory as presented by researchers Storey Helliwell, The Institute of Radio Engineers (I.R.E.), et al., and they thought this theory was as good (if not better than most) at explaining a possible origin of Crop Circles. What seemed fascinating to Don and James was that Marion Island, also home to a secretive military installation, was at the far end of a magnetospheric duct, i.e., at a conjugate point to south-western England. Perhaps lightning storms, enhanced by the odd geography of Marion Island, or perhaps, a secret military experiment there, were generating great bursts of electromagnetic energy that would enter a magnetospheric field-aligned duct and arrive in England as a powerful whistler, which would cause Crop Circle by perhaps affecting the stems of the wheat stalks in odd manners.

From a scientific point of view, however and from what both amateur and professional whistler listeners and researchers have found it is hard to believe whistlers were so concentrated in their energy area and also "intelligent" to create such lovely patterns in the English fields. Radio engineers and other "technical" people involved with radio waves generally know that it is impossible to confine a radio wave to an area or volume less than 1/2 its wave length. In the case of whistler energy emerging from the confines of its duct and resuming the velocity of light (300,000 km/186,000 miles per second), its (full-wave) size is from 19 miles at 10 kHz to almost 190 miles at 1 kHz pretty large! Mike Mideke eloquently expressed this reality in the final few paragraphs on page 27 and the first few paragraphs of page 28 of CROP CIRCLE SECRETS. Part 2. Also, the power of a radio wave (also known as the "field-strength") from even the strongest and loudest whistlers ever heard and/or recorded by anyone have never been as strong as the VLF radio waves generated from nearby lightning storms, though the lesser energy from whistlers is of course sustained much longer than the split-second burst of energy from a lightning stroke, and, or course, whistler radio energy does differ substantially from a lightning bolt's.

While whistlers would hardly seem to be so super-concentrated in their strength and focal area to cause such intricate and sharply defined impressions in plant material like crop circles, data gathered in the past 35 years by manned and un-manned monitoring stations located worldwide has found that whistlers do occupy a "footprint" that is-they are heard loudest at a given location at ground level, and then gradually weaken as one moves concentrically away from "ground zero". Most whistlers are heard in a 500 to 1000 mile radius from the exit point region of its duct, though it's sound characteristics may be different from one place to another within this whistler reception area. Whistlers also tend to cluster in the middle and upper-middle latitudes of the globe between 25 and 60 degrees north/south, and are rarely heard at the "geomagnetic equator" a wandering latitudinal line on the globe at the half way point of any great-circle line drawn from Earth's magnetic north pole to Earth's magnetic south pole.

Most of the continental United States and southern Canada are between these latitudes to hear not only splendid whistlers but also beautiful VLF radio "chorus" from Auroral displays. The same goes for most of Europe, especially the British Isles and Scandinavia. In the Southern hemisphere; southern Argentina and Chile; the southern parts of Australia, particularly Tasmania; New Zealand; and perhaps, the Cape Horn region of South Africa, are similarly at the right latitudes to hear whistlers and chorus. The South Island of New Zealand and the Tierra del Fuego region of South America, plus the Antarctic Peninsula, are where the good displays of Aurora and auroral chorus can be seen and heard.

Listening to whistlers from near one's home town or on road trips can be very enjoyable and inspiring, but it is even more fun to travel abroad and check out whistler reception in other parts of the world. In late May of 1992, my father and I went on holiday to Ireland, enjoying a 12-day coach tour of the entire country. I brought my pocket-sized WR-3 whistler receiver, hoping to catch and record some "Irish whistlers". The first night happened to be at the Clare Inn not far from Dromoland Castle and Newmarket-on-Fergus. Surrounding this hotel was a beautiful golf course, small lake, meadows, and woodlands. There were only a few powerlines near the hotel and main road to Ennis, leaving much of the golf course and meadowland fairly free from excessive Ac power hum, and therefore, good spots to listen for whistlers, as I tested out a few hours after we arrived bleary-eyed from an all night flight across the northern Atlantic.

In anticipation of hearing whistlers in this quiet and exotic location, I spent much of the pre-midnight period walking around with my Sony LW/MW/SW/FM radio, enjoying the Irish Radio Telefis Eireian (RTE) 1 & 2 radio networks, and the nighttime reception of British and European mediumwave (AM) stations, tape recording much of this reception with my trusty micro-cassette machine. At around midnight, after the BBC on longwave 198 from Droitwich signed-off after the maritime weather report and a cheery "good night", I flicked on my WR-3. Lo and behold, there were nice whistlers, albeit only occasionally, since it still was a bit "early" for the really good whistler shows, which like to start up after 4 am. Catching some sleep in the woods (the hotel was rather far-off at this point) I awoke around 3 am, turned on the WR-3 to hear more whistlers and there were LOTS of them, followed by weak "Auroral chorus" that rose up from the static at around 0400, and remained past my first Irish sunrise, when I drifted back to the hotel room to catch an hour or so of terribly-needed sleep!

That night would prove to be the only place our tour group would spend the night where there was open space the rest of the hotels we stayed in would be located in towns or deep within Dublin, and surrounded by hundreds of electrical lines with no access to large open spaces. I had to be happy with broadcast listening with the Sony, which was always very interesting, anyway. It sure was great to now have natural radio recordings from outside the West Coast.

While scientists and hobby whistler listeners have pretty much determined what regions of Earth are in "whistler country", it is never possible to predict where, at any given time or on any given day, whistlers will be heard loudly, weakly, or even at all. It's conceivable there are days where a whistler hardly occurs anywhere on the globe undeniably there are days and even weeks when not a single whistler is heard by listeners located in otherwise ideal whistler reception regions of Earth, such as Ireland and Europe, the northern tier of the U.S., southern Canada, New Zealand, and so forth.

Conversely, there are days when there seem to be whistlers happening nearly everywhere, as though a giant switch was turned on somewhere in Earth's magnetosphere to issue forth a barrage of weak and strong whistlers too frequent to count! Like weather fronts and hurricanes, it would appear that given a day when things are ripe for strong whistler production, the locations that strong whistlers are heard constantly changes, depending on the locations of lightning storms; the magnetospheric whistler duct beginnings and end points; and the day/night region of the globe particularly the midnight to 6 a.m. period which, as we all know, moves westward 15 degrees an hour.

Thanks to simultaneous whistler monitoring and tape recording efforts, first by 1950's and 60's whistler researchers such as Storey, Morgan, Helliwell, etc.; and later by coordinated amateur and student study groups, hundreds of individual whistlers have been documented. Their findings have determined that the average whistler is heard in an area of about 500 miles radius, though the "big whoppers" may be heard as far as 2000 to 3000 miles from its loudest "arrival point".

One of my favorite examples of intense scrutiny of individual whistlers (by at least 25-30 listening groups or single monitors), was of "The Giant Whistlers" of the morning of March 28, 1992, specifically, of two whistlers occurring about an hour apart. In and of itself, these two huge whistlers are not really different from other strong whistlers which occur in the hundreds and maybe thousands throughout any season, but it WAS remarkable in that they were serendipitously caught on tape by so many listeners, who were participating in a high school student monitoring effort coordinated by a team of scientists and high school professors, called "PROJECT INSPIRE".

The INSPIRE effort was sanctioned by NASA to study the ground reception pattern of radio wave emissions from a special "modulated electron-beam" generator (called "ATLAS") aboard the Space Shuttle (STS-45), which flew in late March, 1992. A schedule of ATLAS "transmissions" was established in hopes that the ground-based VLF radio receivers set up by the student groups would hear its emissions. Unfortunately, the shuttle-based ATLAS unit failed after only two (unheard) transmissions. Fortunately, it was decided the students groups and other individuals should adhere to their INSPIRE listening schedule, and also to "backup" listening schedules arranged for the mornings of March 26-30, 1992. It was during many of these scheduled regular and backup listening periods that many interesting natural radio events were captured, including several strong and powerful whistlers. A very detailed report entitled PROJECT INSPIRE DATA REPORT was produced in August 1992 by Michael Mideke, who was the project's data analyst. It is from this report where the following interesting scenarios of whistler reception has been interpreted.

Back to the two "Giant Whistlers" of March 28, 1992. Bill Hooper, shivering at 4 a.m. Pacific time in his camper near California's Death Valley, started his tape recorders running once again. Bill was one of many experienced whistler enthusiasts who was monitoring individually but part of the larger INSPIRE student effort. He had set up one of the most sensitive whistler receiving stations by far of the entire group participating in the INSPIRE listening sessions, thanks in part to his remote desert location, great distance from any electric power lines combined with plenty of room for a large anten-

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na and very sensitive whistler receivers of his own original design.

At precisely 4:02:38 a.m. PST, or 12:02:38 Universal (Greenwich Mean) Time, an extremely strong (long, 2-hop) whistler was recorded by Bill at his Death Valley listening site. So very strong was this whistler that it briefly overloaded Bill's receiving system. It also produced a "4-hop echo" which was also clearly recorded on his tape. This whistler was also heard and recorded as far away as the U.S. midwestern region and eastern seaboard, but much weaker and "truncated" that is only a fairly narrow spectrum of this huge whistler, in the 3-6 kHz range, propagated eastward. This whistler was also heard weakly to moderately in south-central Texas but again was somewhat truncated there like farther east. Interestingly, a large part of Texas was experiencing heavy rains and lightning storms-whistler receivers in southeastern Texas were picking up very strong, local-like lightning stroke "sferics". If the source lightning of this whistler was in Texas, one wonders how it arrived so loud in the California desert! Perhaps it was generated by lightning strikes somewhere else, perhaps to the north or northeast of California, and far enough as to not really make much of an obvious sferic "pop" in the whistler receiver.

An hour later, a nearly identical strong whistler to the one at 12:02 UT occurred at 13:03:03 UT, this time heard by myself as well as Mike Mideke and others listening in Arizona New Mexico, and even Minnesota. Unlike the earlier big whistler, this particular whistler as heard in Minnesota was stronger. It also was not as "truncated" as was the earlier strong whistler. Interestingly, the sferic generated from the causative lightning stroke was rather weak in California, unlike its whistler. Clearly, on this morning the big whistlers were concentrated in the western United States even though the lightning storms weren't. It should be noted there were days when the whistlers were stronger in the eastern United States and were weaker "out West", and point out how the locations of strong whistler activity change day-by-day and can't easily be tied to where lightning is happening. More on this in a bit.

While we are on the subject of loud whistlers and speculation on their originating lightning strokes, I have an anecdotal whistler story of my own to bring in at this point. While on our September 1993 "Big Trip" in my van and eventually to tour the Canadian provinces of Manitoba westward to British Columbia, Gail and I stopped in the eastern Nevada desert about 20 miles west of Wendover, Utah to catch several hours of sleep. Gail and I had driven most of the night across the Silver

State after a brief stop the evening before at another favorite natural radio listening spot an hour's drive east of Reno, where we had heard and taped a marvelous variety whistlers, some very strong like the ones recorded by the INSPIRE listening groups in March 1992.

Very sleepy and exhausted after 250 miles east-bound on Interstate 80, we took a remote exit off the freeway and headed south down a wide, unpaved road running alongside some railroad tracks. In the dark, we noticed there were powerlines running along the train tracks, but determined to stop in a spot where we could get some sleep and record whistlers (which I was sure must still be roaring), we kept on going until we saw another smooth dirt road branching away at right angles away from the tracks and pesky wires. Making occasional checks for powerline hum with my WR-3, we drove far enough from the wires at least 5 miles-to where I couldn't hear any hum with my WR-3 whatsoever. By this time, we was just too tired (and now cold) to even set up the better WR-4B whistler receiver's antenna. I just had enough energy to get in the back of the van and tuck myself under the covers, falling quickly asleep.

Awaking a few hours later, I noticed it was somewhat light with a slate-gray sky. Time to set up the WR-4's 10-foot copper-pipe antenna and check out the whistler band. As predicted, there were wonderfully loud "growler" type whistlers roaring out of fairly light background sferic static. I hopped back into bed and switched on my cassette recorder, capturing these great whistlers onto a 90 minute tape. My WR-4B whistler receiver was once again proving to be a truly superb receiver with its van-attached pipe antenna and convenient bedside control box, while the trusty WR-3 made a nice spot checking receiver. With the WR-4B, I could snuggle under the covers and run tape even if I fell asleep while recording. It certainly was a vast improvement over holding our WR-3's out the vehicle window or clamped in the van's door as we did that August 1992 night up the California Coast, and Mike Mideke even commented in a letter: "I was wondering when you'd get out of hand-held mode"! This September 17, 1993 morning, Gail and I were having a nice time parked once again in the beautiful high desert surrounded by beautiful mountains, pungent sagebrush, whistlers roaring in the headphones, and few cares in the world.

The entire 4,500 mile trip through 10 states and 4 provinces was completed in about 2 weeks and over 10 hours of natural radio recordings, including wonderful "auroral chorus" while watching the northern lights dance overhead in Alberta. While many of my whistler and chorus tapes were recorded while tired, semi or fully asleep, I was not able to critically scrutinize what things I was recording until I got home. Herein lies the beauty of taping what you hear events can be listened to again and again in my case usually for the sheer beauty of Earth's natural radio sounds, but also for scientific analysis if necessary. Also, subtle elements are sometimes missed while monitoring live due to fatigue, the distraction of beautiful surroundings, and so forth.

What I can explain about those great big eastern Nevada whistlers of September 17, 1993 is as follows: They were coming from rather weak but distinct and clean "tweeking pops", the kind which are produced by fairly distant ground strikes. Now, I've listened to a lot of lightning sferics while watching the lightning strikes making them, and the sounds of lightning static can be as varied as the visual strikes. I've noticed that the big, bright, single cloud to ground lightning strikes can deliver a very loud but clean "pop" in the whistler receiver's output. Cloud-to-cloud lightning, sometimes tripping other nearby in-cloud lightning, sounds more "crackly" or like the crushing of a Walnut in a nutcracker.

Anyway, interspersed amongst the numerous weak sferics and occasional, huge whistler generating popping tweek were occasional strong and semi-local lightning sferics dry sounding and not tweeking that were generating very weak and quite diffuse ("hissy") whistlers. These strong sferics were coming from lightning within about 50-100 miles of my listening location. Seems they just weren't generating big whistlers or if they were, the whistlers were arriving SOMEWHERE ELSE strong but distant enough to explain their rather weak strengths near their source lightning. So, this idea of lightning stroke energy entering a duct or ducts to travel to the magnetic conjugate and then back again to the general area of their generating lightning strokes is a fairly simplistic explanation and not entirely satisfactory. And, as simplistic explanations tend to do, it fails to consider more complex events taking place...

It is my supposition that, somewhere, as they merrily arch along the magnetic-field lines, whistler ducts can cross, combine, and/or excite each other. In my mind this helps explain why 2-hop whistlers don't always "land" near where their originating lightning stroke occurred, but can wind up a thousand or more miles away! If you will, whistlers can "jump rail" and enter adjacent ducts, winding up curiously far from where they should arrive whistler wanderlust. As such, it is hard to believe southern England and Marion Island would have a dedicated whistler duct connecting them "together" and transferring Marion

Island Lightning into Wiltshire whistler crop circles! More than likely, lightning energy from Marion Island winds up occasionally as a short whistler in southern England, but maybe an hour, day or week later, is sending whistlers into France, Spain, Iceland, or maybe Moscow and these wandering whistlers are "bouncing back" as 2-hop whistlers now even more removed from their parent lightning storms!

I think conjugate points (and their associated "impact zones"), caused by variations in the exact position of Earth's magnetic field, can vary daily and even hourly call it "conjugate end-point drift". If the solar wind is pushing against the magnetosphere, either gently or as can be the case after solar flares and "coronal mass ejections" from the Sun rather violently, then the motion of Earth's magnetic field lines and any whistler ducts present within them must also get tugged and pulled to various degrees from their "normal" positions. This and my suggested whistler duct crossings, jumps, and re-combinations must be partial explanations of why lightning in Texas sometimes causes strong 2-hop whistlers in California, or why Nebraska lightning generates huge whistlers in Manitoba that are weaker in Nebraska. Where was the Nevada lightning of the morning of September 17, 1993 sending strong whistlers (if any) to? Where were the rather weak lightning sferics that generated such giant eastern Nevada whistlers? I can also ask, just where was the lightning that spawned southern England's artistic whistlers?

One can't neatly package the fascinating whistler phenomenon with magnetic conjugate points, lightning stroke counts, fixed impact zones, et cetera, et cetera, and expect to easily explain what in reality is a mind-boggling dynamic process that changes like a kaleidoscope and never repeats. While it is intriguing and fun to try and scientifically unravel the phenomenon of whistlers, part of their allure is that they are just there to be listened to they are as nice to hear as sunsets are to see, and the reasons for their existence must sometimes take a back seat to the beauty of their tones.

Neither myself or anyone else have yet to determine if there are "special places" where, perhaps due to local terrain or geology, whistlers are louder and more frequent than average. But, they may exist somewhere. Intriguingly, Edson Hendricks, a researcher into the mysterious "Marfa Lights", heard extremely loud whistlers issuing forth from a very crude and seemingly insensitive whistler receiver during a display of these strange and spooky colored balls of lights occasionally seen in the desert near Marfa Texas for nearly 50 years. Ed was listening right near powerlines, and their "hum"

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would have surely been overpowering to more sensitive whistler receivers like my WR-3/4's or BBB-4, and also Mike Mideke's fine RS-3/4's, but Ed tells of these very pure whistler-like notes far stronger than the weakish background hum, as heard in the output of his simple receiver. Something is going on there in west Texas that needs further checking out, and it again points to the great need for more people to join in the whistler listening movement. We would know vastly more about whistlers if there were as many people listening to whistlers as were watching the prime-time fare on television a silly and hopeless wish but even 100 or more people joining the whistler listening movement and coordinating listening schedules would give a clearer idea of when and where whistlers are coming and going.

If whistlers aren't enough of a fascinating pursuit, there are a host of other natural radio "sounds" which can be heard at the 0.1-10 kHz audio-frequency portion of the radio spectrum to keep enthusiasts hooked on these Earth radio sounds. One of the more common (but less frequent than whistlers) are "chorus", which consists of a series of sharply-rising notes, called "risers". This fairly common phenomenon (but not as common as whistlers) can mimic the sounds of a flock of birds chirping, frogs croaking, or seals barking. Chorus occurs during magnetic storms, when Earth's magnetosphere receives a barrage of high-speed energetic particles cascading into it from solar flares on the Sun or from energy ejections from the Sun's "coronal holes" which allow to escape the Sun in streams traveling at sub-light speeds. This phenomenon of magnetic storms is also responsible for the Aurora Borealis and Australis the Northern and Southern Lights seen in the sky at higher latitudes close to Earth's Arctic and Antarctic regions. Chorus can happen during visible aurora and is called "Auroral Chorus" this sometimes can also be heard over a widespread area at around local sunrise, when it is called "the Dawn Chorus". Often accompanying Earth's magnetic storm associated auroral displays and natural radio chorus is "hiss", "wavering-tones", and other endless varieties of natural radio sounds.

Just when lightning seemed a rather common and well studied phenomenon, awesome as it is, Mother Nature throws another "wow!" at mankind. It seems we can now add the terms "red sprites" and "blue blobs" to our lightning storm vernacular. I am fascinated by recent videotaped evidence presented to the world scientific community and also general public pertaining to massive red and blue bursts of lights occurring as high as 20 to 30 miles above lightning storms. For years, pilots of high-altitude aircraft were reporting sightings of strange blue and red lights seen above lightning storm clouds which were occurring at the same time as lightning flashes in the clouds below.

In the summer of 1994, scientists from the University of Alaska Geophysical Institute in Fairbanks, Alaska were at last able to very clearly videotape these incredible lights using high-speed video cameras located on the ground and aboard two aircraft flying over storms in the U.S. Midwest. As though squirted out of a spray bottle, bursts of red light can be seen bursting upward in a stream right over lightning strokes and flourishing in a great cloud of light, lasting for about 1/10th of a second.

Fascinating as these baffling red and blue lights are, what's even more intriguing to natural radio listeners like myself is a quote from one of the researchers, David Sentman of the U. of Alaska Geophysical Institute, who says that the radio signals, when played through an audio speaker "sound like eggs hitting a griddle". Sounds like the hundreds of thousands of "crackling" sferics I have heard and tape recorded through the years, many of them (but certainly not all or most) have set off nice whistlers. I have always pondered at the sheer LENGTH of many of these lighting sferic crackles quite a few of them are about a second in duration, and there are occasionally crackles which carry on for almost 2 seconds! These times seem far longer than any actual flashes of lightning I've ever witnessed, although it would seem lightning strokes can trigger other lightning strokes (via these immense radio energy impulses), seemingly supporting the reasons for such lengthy sferic "crackles". Now, it would seem I've been hearing the radio sounds of sprites and blobs I wonder if re-naming my WR-3 "Whistler Receiver" to a "Sprite & Blob Receiver" might be appropriate. Seriously, there is thought amongst whistler listeners that these weird lightning strike emissions are what may be causing whistlers, since they offer visible evidence of a linkage of energy from above the lightning storm clouds toward the ionosphere. They do not occur during every lightning stroke, just like whistlers do not happen after every lightning stroke.

Since the Aurora Borealis and Australis more commonly referred to as the Northern and Southern Lights also generate fantastic VLF radio sounds, it remains a dream of mine to video-tape the Northern Lights while simultaneously recording their radio emissions onto the audio sound track. I have watched aurora in Canada dance in the skies and listened to their beautiful whistling and squawking in the whistler receiver bursts in intense aurora would also create bursts of auroral radio sounds. I understand the U. of Alaska Geophysical Institute in Fairbanks (the same folks studying the "Red Sprites" and "Blue Blobs" over lightning storms) has created an extremely sensitive (equivalent to 2 million ISO) video camera. They videotaped beautiful auroral displays in the Alaskan night-time skies with astounding high clarity and detail, something never before achieved. Most auroral photography requires time-exposures with still cameras to turn out brightly. But then, the fine detail of the auroral curtains becomes smeared due to the motion of the auroral displays.

The most basic receiver required to pick-up and record whistlers and all of the other Natural Radio signals of Earth is a tape-recorder audio amplifier connected to a wire antenna (aerial) of sufficient length to transfer enough radio energy into the tape-recorder's audio amplifier to successfully record them. In actual practice, however, this crude tape-recorder/audio-amplifier "receiver" will most likely also intercept your local broadcast station transmitting in the long or medium-wave band as well as other signals, and it may not have enough "sensitivity" since tape-recorder inputs rarely are well "matched" in impedance for wire aerials but prefer microphones and such.

Fortunately, whistler receivers are rather easy to construct and are for the most part less complicated than $5 AM "pocket" radio. A handful of parts and a couple of fairly commonplace transistors can form the basis of a very good whistler receiver that will perform very satisfactorily and almost as well as the professional study units that cost upwards of several hundred dollars. This whistler receiver circuit has proven to be a very fine "basic" whistler receiver that I have been using (along with several other VLF receiver designs) during the past 5 years of my Natural Radio recording efforts. This receiver is called the McGreevy BBB-4 (Bare Bones Basic, version 4). It is also similar to Mike Mideke's RS-3 and RS-4 designs except it does not include the second audio filter that is present in Mike's designs, and the "front-end" of the BBB-4 is of the design I primarily employ in my whip-antenna receivers.

In closing, I invite readers to join in and listen to the wonderful radio sounds of Mother Earth. You needn't be interested in science or be a radio buff, but need only to have the desire to lend an ear to the extraordinary yet ordinary. Like star gazing, Natural Radio listening redirects the mind and heart toward the wonder and beauty of the natural world.

Electric Enigma

The VLF Recordings of Stephen P. McGreevy.

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Irdial-Discs
Po Box 424
London SW3 5DY

irdial@irdialsys.win-uk.net
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1
Chorus, Sferics, Tweeks & Whistlers

Welcome to the realm of very low frequency (VLF) "Natural Radio"! A rapidly growing group of people are interested in monitoring the Earth's huge variety of naturally-occurring VLF phenomena, whether for casual curiosity and aesthetic appeal or for serious research purposes. Naturally occurring VLF radio emissions of Earth will occur in the 0.2 to 11 kHz (audio frequency) VLF electromagnetic spectrum.

Planet Earth (along with several other planets in the Solar System including Venus, Jupiter, Saturn, Uranus, and Neptune) produces a variety of naturally occurring radio emissions at the lowest end of the radio spectrum. These emissions are primarily in the form of electromagnetic (radio) impulses generated by the planets' ongoing lightning storms, and from the Sun's solar wind interacting with the magnetic envelope surrounding the Earth, called the "Magnetosphere." These VLF naturally occurring radio emissions are the subjects of ongoing scientific research by both amateur and professional groups, and are being monitored both on the ground by specialized VLF receivers such as the WR-3 and by unmanned space probes and satellites.

It is at these lowest frequencies of the radio spectrum (0.2 to 10 kHz) in which no man-made signals are assigned, that planet Earth's own mysterious radio emissions have been happening for eons. These fascinating "sounds" are "primal radio", indifferent to the affairs of humankind and insight into the causes of these ancient phenomena has only begun to be unraveled in the past four decades.

Besides 50 or 60 kHz (and harmonics) alternating-current power line "hum" from electric-utility power grids, the most noticeable sounds are going to be the snap, crackle, and pop of lightning-stroke electromagnetic impulses (called "atmospherics" and "sferics" for short) from lightning storms within a couple thousand miles of the receiver; the more powerful the lightning stroke or the closer it is to the VLF receiver's location, the louder the pops and crashes of sferics will sound in the headphones. Several million lightning strokes occur daily from an estimated 2000 storms worldwide, and the Earth is struck 100 times a second by lightning. At times the receiver's output is a cacophony of crackling and popping sferics from lightning strokes originating in storms near and far.

These huge sparks of lightning strokes are powerful sources of electromagnetic (radio) emission throughout the radio frequency spectrum--from the very lowest of radio frequencies up to the microwave frequency ranges and the visible light spectrum. However, most of the emitted electromagnetic energy from lightning is in the very lowest part of the radio spectrum, from

0.1 to 10 kHz. The radio pulses produced by lightning strokes travel enormous distances at these very-low radio frequencies, following the surface of the Earth as "ground waves." It is interesting how generally quiet and lightning sferic-free the hours are from just after sunrise to mid-morning, when thunderstorms tend to be at their minimum. Later, the crackling and popping of lightning sferic activity picks up as afternoon thunderstorms build in numbers and intensity. This is due to thermal heating and convection, especially in the summer and autumn months, when, by sunset, the sferics (snap, crackles, and pops) are roaring in a varied and ever-changing texture as lightning storms rage on into the evening. Weather monitoring agencies em- ploy special receivers and direction-finding lightning sferics in order to determine where lightning strikes are occurring and the potential for wild-fire ignition, hazards, to aviation, and damage to electric power utilities from those lightning strikes.

While to some, the popping and crackling of lightning sferics may sound like "static", keep in mind that each click or pop is a lightning stroke flashing somewhere, and note just how much lightning is going on even though your local weather may be cloudless. Additionally, distinct seasonal variations in the density of moderate to strong lightning sferics are very noticeable. During the winter months in the mid-latitudes, when the electrical storm density is generally at its lowest, the amount of strong sferics are also at a minimum. Mid-winter, especially in the higher latitudes north of 40°, can be quiet with little lightning sferic activity. However, a weak but continuous background level of lightning sferics may be audible between the few strong sferics--these are from the higher amounts of lightning storms occurring in the tropics and from the opposite hemispheres' summer lightning storms. Contrast that to local summer evenings, when there is a continuous "roar" of lightning sferics heard. The Earth is "awash" with lightning storm activity!

At night, many of the popping and crackling sounds of sferics take on a pinging/dripping sound, called "tweaks", and can be quite musical. Tweaks are a result of the impulse path from the lightning stroke to the receiver being influenced by the Earth surface-to-ionosphere (D and E layers) region, which is about 45 to 75 miles in height, measured vertically during the nighttime hours. This region between the lower ionosphere and surface of the Earth acts as a "duct" or "wave guide" at these VLF radio frequencies, which have wave- lengths ranging from 10 miles/29 km. at 10 kHz to over 186 miles/289 km. at 1 kHz, allowing lightning stroke impulse energy to travel considerably farther than during the daytime. As the energy travels and is reflected within this Earth-ionosphere wave guide, the energy undergoes a "dispersion" effect whereby the higher frequencies of the lightning impulse arrive before the lower ones within a fraction of a second. The wave guide dispersion effect abruptly cuts off below about 1.5 to 2 kHz (1,500 to 2,000 Hz) in frequency, resulting in the ringing/pinging "tweak" sound which is also centered around 1.5 to 2 kHz. This "tweak" sound is the lowest resonance frequency of the ionosphere-Earth surface wave guide. This is similar to what sound waves experience in a pipeline.

If you have your hands inside a pipeline between one to three feet in diameter, you will notice a sound similar to the radio sound of tweaks. Because the Earth surface to ionosphere wave guide cannot support radio energy below about 1.5 kHz, the dispersion effect is cut off below the frequency, creating the resonance-like pinging and ringing sound.

The sounds of tweaks can change on an hourly basis from night to night, with the ringing and pinging effect intense and musical at times, especially at night in summer and autumn when there is a higher density of relatively strong sferics. Only a few pops and crackles of sferics may be "tweaking", or all of them can be, and the tweaks may sound "crusty" or be very clean pings and rings. Tweaks can be indicators of the condition and height of the lower layers of the ionosphere to researchers.

In addition to the sounds of lightning sferics and tweaks, you may be hearing downward falling musical notes ranging from nearly pure to "swishy" or "breathy" sounding tones from ½ to over four seconds in duration. These are "whistlers", which sometimes happen a couple of seconds after the static crashes and pops of sferics from lightning strokes. Whistlers generally sweep downward in frequency from about 6 kHz to around 0.5 kHz but the lower cut off frequency does vary remarkably as conditions change, and the upper frequency of whistlers can start higher than 10 kHz. Whistlers sounds quite fascinating. Like "science fiction" sound effects, they are one of the more common Natural Radio sounds you can hear.

The Earth's magnetic field (the magnetosphere) envelops the planet in an elongated doughnut shape with its "hole" at the north and south magnetic poles. The magnetosphere is compressed on the side facing the Sun and trails into a comet-like "tail" on the side away from the Sun because of the "Solar Wind", which consists of energy and particles (plasma) emitted from the Sun and "blown" toward Earth and other planets via the Solar Wind. Among the charged solar particles caught in the magnetosphere are ions (electrically charged particles), which collect and align along the magnetic field "lines" stretching between the north and south magnetic poles.

These magnetic-field aligned ions bombarding Earth's magnetosphere form "ducts" which can channel lightning-stroke electromagnetic impulse energy. Whistlers sound the way they do because the higher frequencies of the lightning-stroke trade energy travel faster in the duct and arrive before the lower frequencies in a process researchers call "dispersion." A person listening with a VLF receiver in the opposite hemisphere to the lightning-stroke (at the far end of the magnetospheric duct path) will hear this "one-hop" falling note whistler. One-hop whistlers are about 1/3 of a second in duration.

If the energy of the initial one-hop whistler gets reflected back into the magneto-ionic duct to return near the point of the originating lightning impulse, a listener there with a VLF receiver will hear a "pop" from the lightning-stroke impulse, then roughly on to two seconds later, the falling note sound of a whistler, now called a two-hop whistler. Two-hop whistlers are about one to four seconds in duration depending on the distance the whistler energy has traveled within the magnetosphere. One-hop whistlers are usually higher pitched than two-hop whistlers.

The energy of the originating lightning stroke may make several "hops" back and forth between the northern and southern hemispheres during its travel along the Earth's magnetic field lines-of-force. Re- searchers have observed that the magnetosphere seems to amplify and sustain the initial lightning impulse energy, enabling "multi-hop" whistlers to occur, creating long "echo-trains" in the receiver output which sound spectacular! Each echo is proportionally longer and slower in its down- ward seeping pitch and is also progressively weaker. Conditions in the magnetosphere must be favorable for multi-hop whistler noises to be heard. Using special receiving equipment and spectrographs, researchers have documented over 100 echoes from particularly strong whistlers-- imagine how much distance the energy from the 100th echo has traveled--certainly millions of miles/Km! Generally, only one to two echoes are heard if they are occurring, but under exceptional conditions, several echoes will blend into a collage of slowly descending notes and can merge into coherent tones on a single frequency quite unlike any sounds heard outside of a science-fiction movie!

It should be reiterated that strong two- hops (and echoes) can occur from lightning that is within a couple of hundred miles from the listener location, but perhaps from lightning over 100 miles distant. You may notice that "louder" sferics (i.e. closer lightning strokes) often do not trigger the loudest whistlers, if they do so at all, but then a loud whistler may come howling through from a relatively weak sferic from quite distant lightning. This is because the lightning impulse sferic energy may propagate with- in the earth-ionosphere region for considerable distance before entering a magnetospheric "duct." A majority of whistlers are heard ULC during periods of locally fair weather. In fact, Many extremely loud "big whistlers" are heard without any preceding lightning sferic audible whatsoever, indicating the initiating lightning strokes of those strong whistlers are far away, possibly over 3000 miles!

Whistlers are best heard in 30° and 55° north latitude in North America, the prime latitude being 40° and 50° north.

Occasionally, shortly after sunrise and even extending into the mid-morning, a phenomenon called "Dawn Chorus" may occur. Dawn chorus can resemble the sound of a flock of birds singing and squawking, dogs barking, or sound like whistlers raining down by the hundreds- per-minute (called a "whistler storm"). Dawn Chorus results from hundreds of overlapping, rapidly upward rising tones that can be continuous or appear in bursts, called chores trains. Chorus trains sound fascinating--the bursts of chirps and squawks (risers) seem to suddenly commence, and over the course of two to five seconds, weaken and fade away, then re- peat over again, often in different pitches. During a chorus train, the sounds some- times seem to be echoing or reverberating back and forth until fewer risers happen, then there may be a brief pause before the next chorus train commences. Chorus trains seem to be harmonically related--a chorus train's center audio frequency may alternate randomly, first centered on about 1 kHz, then another chorus train will suddenly start up one octave higher at around 2 kHz, or maybe 4 kHz. Bursts of chorus trains happening at different octave can overlap in a beautiful cacophony.

Dawn chorus occurred several times a month during years of high sunspot activity (1989-1993) after solar flares and/or coronal mass ejections on the Sun send a barrage of charged particles into the Earth's magnetic field, causing a geomagnetic storm and also producing Aurora (the Northern and Southern Lights). In years of low-sunspot counts and few solar flares (1994-1997), coronal mass ejections from the Sun can still cause magnetic storms once or twice a month.

Chorus doesn't always only occur at dawn, especially for listeners located at higher latitudes, particularly in southern and central Canada (50 to 55° north latitude), Alaska, and in northern Europe. This auroral zone is source to a vast amount of natural VLF phenomena. When a solar disturbance on the Sun (such as the solar flare or coronal hole mass ejection) sends highly charged and high-speed particles and ions towards Earth via the Solar-Wind, Auroral displays often occur, and are visible to people near the auroral zone oval. Earth's magnetic field also undergoes a "storming" process as well, called a "magnetic storm." During auroral displays, chorus is often heard, as well as "hiss" of various pitches, "sliding-tone emission" which eerily and weirdly rise in pitch slowly over one to several seconds duration. The chorus which occurs during displays of Aurora is called "Auroral Chorus".

Both Auroral chorus and dawn chorus are related in that they occur during magnetic storms. The more severe the magnetic storm, the farther south away from the auroral zone and the louder the chorus will be heard. The Auroral Zone "oval" surrounding the magnetic poles expands during magnetic storms and reaches farther southward (and the southern Auroral Zone "oval" in the southern hemisphere expands farther northward). Aurora is a daytime phenomenon, but it is not visible to the naked eye due to daylight illumination of the sky. Particularly intense events of nighttime and dawn chorus can get loud even for listeners below 40° north latitude (in the U.S.), and point to the evidence that aurora can reach southward into the middle latitudes despite it not being visible.

The maximum intensity region of chorus emissions, like aurora, can spread southward during magnetically disturbed periods. Daytime aurora can be more intense than nighttime aurora, and events of auroral and dawn chorus reveals quite a bit about the nature of aurora.

Even if geomagnetic conditions seem "quiet" and chorus events seem likely, conditions may still be very good for whistlers to occur. However, determining when whistlers are going to happen is still a rather unpredictable affair.

The time between local midnight and an hour after sunrise is when the greatest amounts of whistlers are heard, although dusk to midnight may reveal substantial whistler activity, and even (though not very often) loud whistlers may be heard a couple of hours before sunset. Over the long term, the period from two hours before sunrise until an hour after sunrise is the optimum time to listen for natural VLF phenomena of all sorts, as the mount of sferics (lightning stroke pops and crackling) are less---natural VLF phenomena are not as "buried" under the sferics as in the evening when lightning storms are more numerous. Also, magnetospheric conditions are optimum around morning twilight time.

Intense whistler events of short duration can occur at any time between just before local sunset through one to two hours after sunrise. A good whistler event that is happening at 10 p.m., or even at sunset may not be occurring later on that night at the usual optimal sunrise period, so don't rule out the evening hours to listen, especially during geo-magnetic storms.

On several mornings a month, one whistler a minute may be heard on average, but as is often the case, whistlers will not be heard at all. Occasionally during a geomagnetic storm. caused by a solar flare, over 100 whistlers a minute or more may be heard--called a "whistler storm"! Whistlers may or may not have echoes may be few and far between but occur loud, or may occur often but quite weak. The sound characteristics intensity, and number of whistlers can change rapidly hour to hour. Everything depends upon the sensitivity and conditions of Earth's magnetosphere and location of lightning storms and magnetospheric ducts in relation to the listener.

Whistlers are seldom heard mid-day, except during unusual conditions occurring with a geomagnetic storm and when lightning is within a few hundred miles of the listener. Unfortunately, on a good number of days during the year, there will not be any whistlers audible even though there is plenty of lightning activity and sferics with- in a few hundred miles of the receiver. Often elusive, whistlers may not be heard for days or weeks at a time. Again, it is hard to predict when whistlers are going to occur based on the geomagnetic indices, but they are generally more common in the spring and fall, surrounding the equinoxes.

Auroral chorus, like whistlers, is best heard between midnight and sunrise. Dawn chorus tends to peak in intensity between sunrise and one hour later.

Listeners to natural VLF radio phenomena shouldn't be discouraged after several listening sessions, whistlers, chorus, or other VLF phenomena sounds are not heard. Soon. you will be rewarded with a myriad of fascinating sounds from whatever VLF phenomena is occurring at the time you listen. Remember, weather and outside temperature permitting, the period around local sunrise will be the most rewarding time to listen. Natural Radio sounds can sound eerie and awe-inspiring, especially when one realizes it is all naturally occurring--not man-made and that these radio emissions have been occurring for millennia.

Stephen P. Mcgreevy1995

2
Classification of VLF Sounds

Omega: All of the recordings presented on these 2 CDs have, to a greater or lesser extent, a high-pitched beeping sound toward the high-frequency end of audibility. These are the sounds of the worldwide Omega Radionavigation System. Omega--rapidly becoming obsolete thanks to the advanced GPS (Global Positioning System) satellite navigation system--consists of eight 10,000 watt transmitters in the following locations: Australia (Victoria), Japan; Hawaii (Oahu); North Dakota (USA); Liberia (Africa); La Reunion Island; Argentina; and Norway. Each transmitter transmits eight pulses of 0.8 to 1.2 seconds duration, repeating the process every 10 seconds. During each cycle, each transmitter occupies 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 transmits on its own unique frequency on 1 of its 8 transmitted pulses.

Omega receivers sample the relative phase and timing of each Omega signal. Best results are obtained when at least 4 Omega transmitters can be received and analyzed, and the nearest resolution, called a lane, is about 5-6 miles (8-10 km) wide , though in critical regions, supplemental transmitters of very low power may be used in order to increase navigation accuracy. Omega is subject to the same VLF propagation disturbances which affect Natural Radio, particularly during magnetic storms. When Dawn and Auroral Chorus roar, Omega is probably experiencing accuracy problems! There are also daily (diurnal) variations in the accuracy and phase of the Omega signals as day becomes night, which for the most part can be taken into account within an Omega receivers internal microprocessor. GPS does not suffer any of these propagation errors as does Omega, and it is figured that by the year 2005, the Omega system will be shut down.

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 Central and South American countries, it is at 60 Hz. While convenient for long- dis-

tance transmission and easy voltage transformation, AC generates hum in poorly filtered audio equipment and especially in whistler receivers! If this wasn't bad enough, most electrical grids seem to cause the 50 or 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 the--and I'm talking about miles or kilometers near to them!

To have hum-less recordings of VLF phenomena (such as the Eves River or Alaska Auroral Chorus segments), you have to find listening sites far removed from above-ground power lines. Its fairly easy to find absolutely quiet hum-free listening spots in desert and mountainous or tundra regions of North America, Australia, or the remoter parts of Europe and the British Isles (Scottish Highlands particularly) if you're willing to make a few days of it, but finding quiet spots to listen close to home and/or in populated regions such as the English Midlands or U.S. east and Midwest (including farmed areas away from towns) usually mean pesky power lines will be around somewhere, usually alongside the road you're traveling along.

Willingness to walk/hike into listening sites greatly increases your chances that a quiet spot will be found. In most cases, you have to live with SOME background hum, as must I. Thus, some of the recordings on these CDs have some weak background hum. Surprisingly, reasonably quiet natural VLF radio listening spots can be found in places such as large ball fields, large urban/suburban parks away from light poles, farm fields where wires are hidden behind trees, along many beaches (especially if electric wires are belowground), and so forth. It has been found that within southwest London's Richmond Park, quite a few low-hum listening spots exist. This is also true for San Francisco's Golden Gate Parks soccer playing fields.

Naturally-occurring VLF Radio sounds:
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 CDs tracks. An unavoidable part of Natural VLF Radio, 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 odd 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 going on out there! And there IS--a couple million lightning strokes (flashes) occur 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!

Whistlers: Most people get introduced to Natural Radio by hearing a recording of a whistler. Indeed, whistlers are the most common Natural VLF Radio sound besides lightning static, especially for those listening in middle latitudes. 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. In the case of the whistlers recorded in the eastern Nevada high desert, I called those whistlers growlers, since they sounded more like growls than whistles. Of course, there are many samples of whistlers in these CDs.

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 (hopefully!), 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, traveling out into near space and to the opposite hemisphere, where they are heard as a short, fast whistler (explained in more detail in the accompanying booklet with this CD set). 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 becomes magically louder and longer. Essentially, during its globe- hopping round trip, the all-frequencies-at-once radio signal of a lightning 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.

Some (if not MOST days) are DEAD--entirely devoid of the sounds of whistlers, but there can be those days where whistlers rain down too many to count, like 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 sounds 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. Depending on the time of day, location of event (or at least where it was heard), Chorus becomes Auroral Chorus (it was occurring near auroral sources or during visual displays of aurora), or around the pre to post-sunrise period, when it is called Dawn Chorus. Both sound generally similar, though chorus can manifest itself in endless variety.

Chorus is a product of magnetic storms, when events on the Sun, such as a solar flare, or holes in the Suns 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. Phenomena such as Aurora (Northern and

Southern Lights) also increase dramatically during magnetic storm periods, as do such natural VLF Radio sounds such as chorus. Notice the similarities of the various Chorus events presented on these two CDs, yet also notice the 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.

Periodic Emissions: Other sounds different than whistlers or chorus get lumped into this category, but is the term implies, they tend to occur only occasionally (periodically) and in repetitious fashion with a predictable repetition time (period). A fine example of this sound is in the Kenai Crazy Whistlers track, which actually are NOT true whistlers at all but are rarer Natural Radio emissions arising from magnetic storm/auroral phenomena and heard this strongly only at higher latitudes such as Alaska, central or northern Canada, Iceland, northern Scandinavia, or Antarctica. Notice that the Periodic Emissions in this Kenai track seem to trigger subsequent ones (rather like a good tennis volley) until it winds down.

Tonal Bands: Strange-sounding hissy or a multitude of whistling sounds which abruptly begin and end, usually for only 5-10 seconds in duration. Many of these can be heard in the Alberta Auroral Chorus tracks, particularly the longer recording.

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, then gradually tapering off of the effect 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 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. 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 its sometimes more fun just to enjoy their odd sounds. 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!!

Hiss: Also called Hissband, is a VLF radio emission arising directly from Aurora, possibly emitted right from the same location as where the visible light (usually greenish in cast) is produced. 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, it can sometimes abruptly change in volume and/or pitch.

3
Recording Notes

CD 1

1. 7:06

Alvord desert dawn chorus

Sometime around the 17th of August, 1993, the Sun spewed forth a barrage of energetic atomic particles, some of which walloped Earth's magnetic field, causing it to deform and pulsate. The Polar Auroras became more brilliant as well, and were seen farther toward the Equator than usual. The skies dawned a brilliant blue in Oregon's Alvord Desert, and the remnant patches of winter snow upon the uppermost reaches of Steens Mountain shone a bright white. This tranquil scene belied the fact that Earth's magnetic field was undergoing utter chaos. Tremendous VLF radio energy was released by the storming magnetic field. Had they not been outshone by the daylight skies, Auroral Borealis would have danced in the skies overhead. These are the sounds of the Dawn Chorus, a relative of Auroral Chorus but heard into middle latitudes around sunrise. If you listen closely, you will hear the chorus and hiss gently rise and fall subtly every 10 seconds or so. This is the actual sound of Earth's magnetic field pulsating in and out. Because it was local summer, the radio energy static of lightning storms across North America was denser and more vigorous than if it were in winter.
Techie notes: (Strong Dawn Chorus recorded in the Alvord Desert of southeast Oregon. Some of the strongest dawn chorus heard south of latitude 45 degrees north. Undulating hiss, chorus, evidence of magnetic field micropulsations. 18 Aug. 1993, 1415 GMT)

2. 5:26

Eves River auroral chorus

Onset of big British Columbia auroral chorus recorded in northern Vancouver Island, BC, Canada, on 21 February 1994 at 1010 UT. Beginning of awesome chorus from visible aurora during major-severe magnetic storm. Extremely discreet, loud barks and squawks (risers). There are also a few pure whistlers with sustained echoing. No powerline hum. very low level of lightning static.

3. 8:10

Fish Rock Road whistler shower

Spring-time in northern California is delightful. The hills are ridiculously green and full of wildflowers, and the air pervades with a potporri of scents. Thoughts turn to the outdoors... Suffering from an intense case of cabin-fever, I tossed a few necessities and a couple of my VLF receivers into the van and headed northward from the San Francisco area into Californias Redwood Empire. With

no specific route plan, I just drove on with the single goal of getting as far from the city as possible. Driving into the night, I spied a sign pointing out a turn-off to Fish Rock Road. I thought to try it out, having never been that way before. It also looked promising as a power-line free road, winding as it did into the coastal mountains peppered with groves of Oak and Redwoods. Locating a nice turn-out suitable for overnight parking, I did another of my VLF-checks, instantly rewarded with gorgeous, almost pure whistlers ringing in my ears! These ones sounded BEAUTIFUL, with a hollow, cavernous quality to them, and the lightning- stroke tweeks were also quite nice sounding. This early April night felt almost warm, and the sky was full of starsthis recording segment is part of several hours of tape run during the night.
Techie notes: (Purer whistlers occurring up to 20 per minute in clusters. Beautiful, hollow, cavernous sound quality to these whistlers. Intense tweeks (with harmonics). Recorded 02 April 1994, Fish Rock Road, Mendocino County, northern Calif at 1100 UT.)

4. 5:24

Dawn chorus with whistlers in the Carrizo Plain

Bisecting California nearly in two, the San Andreas Fault scores a rugged line from the Salton Sea northward to Cape Mendocino, threatening residents with destruction and fury at any time, but also rewarding them with fascinating geological sights. One of the best spots to view the amazing work of this vast fault line is in central Californias Carrizo Plain, where tree-barren, oat-grass covered hills reveal its slow, determined work in the form of offset streams and wierd folds in the hills (clearly visible in satellite photos taken overhead). It is also a fairly nice place to travel to in the winter, shielded from cold, damp fogs shrouding the great central Valley as well as from coastal rain showers. Driving along a smooth dirt road alongside the fault-line hills this New Years Day, we chose a spot to camp with wonderful views of the surrounding terrain and also as far as we could get from a couple sets of large power-line pylons marching away in the distance. A magnetic storm was in progress, though it was winding down from the day before. Camped next to electric lines, we were unable to listen the previous night and now welcomed the electrically quiet location we had found, as well as the amiable weather. At 5a.m. the next morning, this recording segment was made. Weak chirping sounds of Dawn Chorus can be heard (had I been farther north in latitude, the Chorus would have been much louder) and also a good deal of pure whistlers are forthcoming. The weak hum sounds of high-voltage power lines about 4 miles distant can be heard.
Techie notes: (Numerous pure whistlers and background Dawn Chorus chirping sounds. Weak background power-line (60 Hz & harmonics) hum. Taped in the Carrizo Plain, central Calif. 02 Jan. 1994 1300 UT)

5. 4:24

Eastern Nevada growler whistlers

While on our September 1993 "Big Trip" in my van and eventually to tour the Canadian provinces of Manitoba westward to British Columbia, Gail and I stopped in the eastern Nevada desert about 20 miles west of Wendover, Utah to catch several hours of sleep. Gail and I had driven most of the night across the Silver State after a brief stop the evening before at another favourite natural radio listening spot an hours's drive east of Reno, where we had heard and taped a marvelous variety whistlers, some very strong like the ones recorded by the INSPIRE listening groups in March 1992. Very sleepy and exhausted after 250 miles east-bound on Interstate 80, we took a remote exit off the freeway and headed south down a wide, unpaved road running alongside some railroad tracks. In the dark, we noticed there were powerlines running along the train tracks, but determined to stop in a spot where we could get some sleep and record whistlers (which I was sure must still be roaring), we kept on going until we saw another smooth dirt road branching away at right angles away from the tracks and pesky wires. Making occasional checks for powerline hum with my WR-3, we drove far enough from the wires--at least 5 miles-to where I couldn't hear any hum with my WR-3 whatsoever. By this time, we was just too tired (and now cold) to even set up the better WR-4B whistler receiver's antenna. I just had enough energy to get in the back of the van and tuck myself under the covers, falling quickly asleep. Awaking a few hours later, I noticed it was somewhat light with a slate- gray sky. Time to set up the WR-4's 10-foot copper-pipe antenna and check out the whistler band. As predicted, there were wonderfully loud "growler" type whistlers roaring out of fairly light background sferic static. I hopped back into bed and switched on my cassette recorder, capturing these great whistlers onto a 90 minute tape.
Techie notes: (Eastern Nevada Big Growler Whistlers, a few with enormous strength with accompanying triggered emission chirp and faint echo. 17 Sept. 1993, 1330-1500 UTC Recorded 30 km southwest of Wendover, NV. Some loud, semi-local lightning sferics initiating very breathy, windy sounding whistlers, though not as loud as the big growlers. Several loud lightning static bursts digitally removed from track and edited/compiled into several whistlers per minute rate.

6. 4:12

Slow-falling Alberta whistlers

(preceding the Auroral Chorus several hours later)
About half an hour before sunset, we reached Alberta, and stopped briefly to snap a photograph of us standing next to the "Entering Alberta, Wild Rose Country" sign. Whew!, we had crossed into yet another huge and awesome province. Remembering that the next morning was "VLF Sunday"a date arranged in advance by Michael Mideke to record natural VLF radio at pre-arranged times, we started looking for a back road off of what was now Alberta Provincial Highway 12. We were in a

sparsely populated and rather hilly area near Kirriemuir and Monitor, AB, and hoped we could find a location to spend the night which was away from electric power-lines by at least a mile. As we drove down the highway, we tossed our heads left and right, spying a few interesting looking dirt and gravel roads on both sides of the main highway.

Braking to a halt on the empty highway, we did yet another of our multiple point turns in the van and headed back the other way. The first gravel road we chose ended up looking a bit too well-traveled and also not far enough from AC power-lines. The second choice couldn't have been better--a lightly rutted dirt (and mud) track into some low hills and trees next to an arroyo. The road terminated at what appeared to be ranch homestead with only a trailer and fallen-down windmill atop one of the small hills. A quick check with my WR-3 confirmed this level hill-top location was great for natural radio listening, being quite some distance from electric wires. With some trepidation since we didn't like the idea of trespassing, we walked up to the trailer prepared to ask permission to park nearby. But, nobody was home and the place looked like it had been unoccupied for at least a week, so we elected to stay and set up the WR-4B VLF receiver's antenna mast then ate dinner while watching the perfectly clear sky turn colors as night approached. It felt like it was going to be a cold night, though the very dry air would make the cold bite less, and I hoped the aurora would return.

At about 3 a.m. MDT, I awoke and was startled then joyous to see the northern sky filled with a green glow. Looking closer, I also spied faint bursts of green "splotches" moving ("squirting") in a left-to-right (west-to-east) direction! Wow, it was much better than the night before! Apparently, a minor magnetic storm was happening, though I really wasn't alerted to it since the geo-magnetic "indices" put out on shortwave time and frequency standard station WWV from Colorado was reporting only "unsettled" magnetic conditions. I quickly awoke Gail, who had missed out on seeing the fainter aurora the night before. The next thing I did was turn on the WR-4B whistler receiver and start up the tape recorder. I was instantly rewarded by a faint squawking sound of "chorus" as well as weird tones slowly rising then falling. When these weird "sliding tones" would appear, the aurora would slightly brighten and the "squirting green splotches" also seemed to speed up!

By this time, it was at or below freezing, and frost was rapidly building up on the outside of the van's windows though the air inside the van had been considerably warmer--at least until I threw open the back doors and began watching the auroral show while still tucked tightly in my sleeping bag. Gail borrowed the whistler receiver's headphones and listened to the weird VLF radio sounds coming forth, but sleepiness overcame her again and she dozed off. As the initial excitement wore off, I also felt very sleepy again and decided to doze for a while with the tape recorded still running--I at least wouldn't miss out on the great VLF radio sounds.

As the 1100 UTC period approached, I flipped the cassette over and prepared to tape the auroral radio chorus, which by this time was become quite vigorous. Alas, I waited until about 1104 UTC to begin the taping, thinking the appointed monitoring time was to begin at 1105 UTC, when actually it began at 1100. I rolled the tape and taped an entire side of a C-90 (45 minutes) of the fantastic Alberta auroral chorus. This recording was made several hours before the actual aurora was visible, at around 10:45 p.m. local Mountain Daylight Time.

Techie Notes: (Slow descending, breathy/windy sounding whistler trains recorded in eastern Alberta (near Monitor and Kirremuir off of Hwy. 12) at approx. 0445 UT on 26 Sept. 1993. Two hours later, there was visible aurora and the VLF auroral chorus began at approx. 1015 UT Weak background power-line hum (uninterrupted recording of 2:25) to end of side A, repeated at start of side B) NOTE: Also Refer to CD #1, track 8 & 9, and CD #2, track 1

7. 10:57

Kenai crazy whistlers

Kenai Crazy Whistlers--otherwise known as periodic emissions. Rising then falling wavery pure tone emissions of fairly loud stength. Some tweeking sferics. Great recording! Recorded near Skilak Lake on Alaskas Kenai Peninsula on 09 Sept. 1995 at 0945 UT on an overlook looking out over the lake and of beautiful, glacier-topped mountains to the south. The moon was shining and there was also some aurora visible off to the north.

8. 5:07

Alberta auroral chorus

Refer to written story introduction to Selection 6, CD 1. This recording came after the slow descending, breathy/windy sounding whistler trains recorded in eastern Alberta (near Monitor and Kirremuir off of Hwy. 12) at approx. 0445 UT on 26 Sept. 1993. Six hours after the slow whistlers, there was visible aurora and the VLF auroral chorus began at approx. 1015 UT.. Weak background power-line hum (uninterrupted recording of 2:25) to end of side A, repeated at start of side B. This track has the beginning of the Auroral Chorus.

9. 8:40

Alberta auroral chorus

Recorded during visible pulsating aurora (non- discrete) while we were in eastern Alberta (near Monitor and Kirremuir off of Hwy. 12) at approx. 1110 UT on 26 Sept. 1993. Squawking and barking chorus, plus intriguing tonal bands abruptly starting and ceasing. Six hours earlier, there had been very diffuse, slow-falling whistler trains as in Tape 1, recording tracks 6 and 7. Weak powerline hum in background. Overall very beautiful recording! Original recording has some FAINT acoustic sounds picked up inadvertantly via the headphones (talking and Gail snoring!)

CD 2

1. 16:30

Long version of the very beautiful segment of Alberta Auroral Chorus

Recorded during visible pulsating aurora (non-discrete) while we were in eastern Alberta (near Monitor and Kirremuir off of Hwy. 12) at approx. 1110 UT on 26 Sept. 1993. Squawking and barking chorus, plus intriguing tonal bands abruptly starting and ceasing. Weak power-line hum in background. Overall very beautiful recording! (uninterrupted 18:20 recording). Original recording longer, but has some FAINT acoustic sounds picked up inadvertently via the headphones (Steve and Gail talking and also Gail snoring!)

2. 23:37

Eves River Auroral Chorus

Longer recording of the big B.C. chorus, this time starting at 1010 GMT of 21 Feb. 1994. Great squawking, chirping chorus along with the occasional weak pure whistler and numerous echoes after each whistler (called whistler echo trains). At this time, the chorus was really starting up, revealing many variations.

3. 8:17

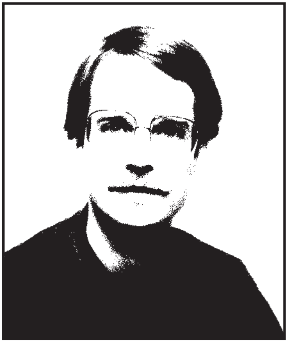
Second recording of Eves River Auroral Chorus

Recorded about 6 hours after the recording on track 2, in the morning at 1600 GMT on 21 Feb. 1994 AFTER SUNRISE (Hence it is now called Dawn Chorus). The squawking/chirping of the Dawn chorus was fairly homogeneous by this time, with vigorous chirping but with little overall variation and sounding quite different from its start-up period in track 2 above. No whistlers occurring at this time.

4. 10:59 and 5. 6:13

Chatanika River Auroral Chorus

Normally heard either during the night at middle-upper latitudes or at sunrise in middle (as in the Alvord Desert Dawn Chorus recording), this was recorded IN THE MIDDDLE OF THE DAY 40 miles northeast of Fairbanks, Alaska, right within the Auroral Zone. It went on continuously for 3 days! Had it not been daylight, the Auroral Borealis would have been dancing in the skies right overhead! Weird squawks, chirps, hiss, and occasional very low groans can be heard. Recorded in central Alaska on 06 September 1995 between 1945-2200 UT. A week long major magnetic storm with accompanying beautiful auroral displays at night and strong auroral VLF chorus audible around the clock! Amazing variety of hissband, tonal emission bands, chorus barks, croaks, whoops, a few whistlers, etc. The weather during the recording session by the Chatanika River was very windy at times, but also sometimes just a slight breeze. Many strong gusts of wind induced some mechanical noise in the WR-3E VLF receiver. A such, the approximately 2 1/2 hours of tape recordings were marred at times by this receiver/mechanical wind noise. However, there are up to 10-minute segments free of this undesired noise.



About the Author

Name: Stephen Paul McGreevy.
Born in San Francisco, California on 5 October 1963.
Began MW Dxing in 1974-5 and SW listening in 1976.
Began Longwave and trans-Pacific MX Dxing in 1982.
Attained General Class Amateur Radio License in 1986 (N6NKS).
August-October 1986, DXed LW, MW and SW from Hawaii.
April 1987 worked several Japanese Amateur stations using 3-5 watts, CW mode on 40 meters from California.
Initial interest in Natural VLF Radio started in December 1988.
Heard first whistler live in eastern Oregon high-desert on crude audio filter and 500 meter wire in June 1989.
July 1989 - July 1990, experimented with various homebrew VLF receivers.
September 1990, developed first successful whip antenna receiver for Whistler Listening.
February 1991, weekly listening and recording of natural VLF Radio began in earnest.
Heard first Dawn Chorus April 1991.
Developed better whip antenna receivers May-July 1991, including WR-3 prototypes. With friend Frank Cathell, developed final WR-3 prototype. October 1991 began selling WR-3.
September 1992, developed WR-4 Van-based VLF receiver and purchased Marantz portable tape recorder. This began period of excellent VLF recording successes.
July 1993, developed enhanced WR-3, called the WR-3E.
September 1993, saw first aurora in Saskatchewan, Canada and recorded Auroral Chorus. Recorded and saw better aurora the following night in Alberta while on 4500 mile road trip.
February 1994, during trip on Vancouver Island British Columbia, recorded stunning auroral chorus during severe magnetic storm.
September 1995, witnesses spectacular auroral displays in central Alaska, and recorded many hours of exceptional daytime auroral chorus with WR-3E.
November 1995, contacted by Irdial-Discs with offer of this CD project.