Natural Radio

News, Comments and Letters About Natural Radio

March 2002

Helliwell Revisited - It all started with the VLF_Group E-mail reflector. Shawn Korgan and others were hearing a bonanza of whistlers out in Colorado last week. Shawn wrote, "The whistlers were absolutely amazing last night! Really low and really deep in space sounding - very clear! I taped about three full hours worth of these whistlers. There were thousands of them! For a storm that only hit K4 it is quite amazing…"

There didn't seem to be any thunderstorms in Colorado, so I decided to check the conjugate point for Colorado. The conjugate point for central Colorado is in the far South Pacific, the nearest land mass being Antarctica. This is an area of very few thunderstorms. My curiosity got the best of me -- it was time to do some research.

Probably the best source on information about whistlers and other Natural Radio signals is Robert Helliwell's 1965 book, *Whistlers and Related Ionospheric Phenomenon*. The book is based on the extensive observations that were made of whistlers during the International Geophysical Year (IGY) in 1957 and 1958.

This observational data is quite useful to those of us who spend our late night and early morning hours listening to whistlers. It layed the groundwork for future research. What we have learned in the 37 years since the book was written has not invalidated this data, but expanded upon it and produced theoretical models and more detailed explanations for the observed phenomenon. The need protect satellites by understaning the magnetosphere and space weather created a need for more study. The availability of these satellites to probe the magnetosphere aided research.

So just what do we know about whistlers?

According to Helliwell, lightning flashes of high energy content tend to produce whistlers. The typical whistler-producing stroke has an energy content of about ten times the average lightning stroke. In the past decade we have discovered that these stronger flashes are of the type that produces red sprites and blue jets. Whether this is just a coincidence, or whether the sprites and jets are involved in the production of whistlers is yet to be determined.

Whistlers happen when an impulse of electromagnetic energy, typically from a stroke of lightning, (I say typically, because manmade impulses can cause whistlers, such as a nuclear blast or pulsed signals from a VLF Radio station), enter a duct in the magnetosphere and follow a magnetic field line to the conjugate point in the opposite hemisphere. These ducts are tubes of enhanced electron density that are field-aligned with the earth's magnetic field.

The propagation through the duct is not like free space propagation of electromagnetic waves, since they are traveling through an ionized medium. The waves are slowed down in a similar manner to light traveling through a prism. Thus waves propagating in the whistler mode experience dispersion; that is, the shorter waves transverse the path faster than the longer waves thus producing the familiar descending tone of the whistler.

A single-hop whistler would originate in one hemisphere and travel through the magnetosphere to the other. (e.g. A whistler from a lightening stroke in Chile would be heard as a single-hop whistler here in the US. A double-hop whistler travels through the duct to the opposite hemisphere, hits the lower boundary of the ionosphere and bounces back to the originating hemisphere. A double-hop whistler has twice the dispersion and thus is usually longer that a single-hop whistler. Of course, under the right conditions, the whistler can bounce back and forth several times – the effect being known as an echo train. During the IGY, a whistler was recorded with over 200 hops.

A little bit about conjugate points. The geomagnetic conjugate point of a given location is a point at the same geomagnetic latitude in the opposite hemisphere that lies along the same geomagnetic longitude line as the original location. For example, Chicago lies at a geomagnetic latitude of 54° North and a geomagnetic longitude of 341°. The conjugate point is at a geomagnetic latitude of 54° South and a geomagnetic longitude of 341°, about 2000 km. West of the tip of South America in the Pacific Ocean.

It is important to note that geomagnetic coordinates are different than geographic latitude and longitude because the earth’s magnetic poles do not coincide with the earth’s geographic poles. The North Magnetic pole is actually about 8° South of the geographic pole in far Northern Canada. The South magnetic pole is in Antarctica but not exactly opposite of the North magnetic pole, which complicates things a bit. In addition, the magnetic poles tend to move around a bit from year to year, so it is important to use a current geomagnetic map if you want good accuracy. You can calculate your geomagnetic coordinates on the web at http://nssdc.gsfc.nasa.gov/space/cgm/cgm.html.

A whistler that follows a single duct will have a sound that is a pure descending tone. Some whistlers, however, sound hissy or breathy. This is due to another property called diffusion. Diffusion is due to propagation through multiple paths, causing many reflections with slight delays thus producing the hissy or diffused sound.

This model is oversimplified, but gives one a general idea of whistler propagation. Geomagnetic coordinates, as described above, are based on a simple dipole model, (i.e. like a bar magnet inside the earth along it’s geomagnetic axis), but in reality it is more complex than that. Interactions with the solar wind and CMEs cause the magnetic field to bend, distort and move. In addition, current research indicates that the ducts through which whistlers travel last on the average of about an hour. The ducts may only be a kilometer or two in diameter and may be hundreds of kilometers or more apart. Studies have shown that whistler ducts tend to drift with time.

So if we needed to be at one end of the duct, with a thunderstorm at the other end in order to be able to hear whistlers, we probably wouldn't be hearing too many. Fortunately, whistlers tend to propagate when they leave the duct and enter the earth-ionosphere waveguide. The typical whistler is heard within a circle of about 1000 km. as determined by the studies done back in the 50's. Also, the energy from a lightning stroke may travel several thousand kilometers in the earth-ionosphere waveguide before it enters a whistler duct -- thus, the reason for whistlers in Colorado.

Propagation through the magnetospheric duct tends to be efficient. In some cases, amplification of the whistler tends to occur. (As in the case of the 200 echoes mentioned earlier.) The main amplitude losses in whistler propagation occur in the earth-ionosphere waveguide. The cause of this is the absorption from the D layer of the ionosphere. This absorption happens on both ends of the path -- as the sferic travels from the thunderstorm to the duct and as the whistler travels from the end of the duct to the listener. Remember that the D-layer fades away at night and reappears after sunrise as the radiation from the sun causes ionospheric ionization. This is why there tend to be more whistlers during the night than during the day, with a sharp drop-off just after sunrise. This does not fully account for the peak that occurs after midnight, which may be due to conditions that produce more or enhanced ducts.

More whistlers are heard in winter, probably because the atmospheric noise is lower at this time of year. During magnetically quiet periods, atmospheric noise tends to be the limiting factor in whistler reception at mid and lower latitudes, where chorus and hiss may be the limiting factor at higher latitudes.

Helliwell's data also shows a much greater occurrence of whistlers in the western US as opposed to the Midwest and Atlantic region. There is at least anecdotal confirmation of this from just following *The Lowdown* correspondence. As better theories are developed on the formation of whistler ducts, we'll gain understanding of locations that seem to have enhanced Natural Radio reception.

Next month we'll review what we know about chorus and other discrete emissions.

Hum Filter - The VLF_Group E-Mail reflector has been abuzz with information on using the Radio Shack Mini Echo Mixer Kit as a comb filter for hum and buzz. Eric Vogel designed the circuit, which is on the web at http://home.flash.net/~evogel/p1b.html. Those that have tried it seem to be getting very good results with listening from their home location. I've ordered one of the kits (part #990-0239) at $19.95 and hope to be able to do some monitoring from home.

Spring Equinox Coordinated Listening The Spring coordinated listening weekends for this year are March 16 & 17 and March 23 & 24. Dust off your receiver and head for your quiet spot. For logging information, refer to the March, 2001 issue of *The Lowdown*. Write or E-Mail me if you don't have that issue and I'll send you a copy of the logging instructions.

More Electrophonic Studies - Here is an interesting article just released on meteor sounds. These sounds apparently are created by electromagnetic frequencies lower than the VLF spectrum as meteors couple with energy in the ionosphere! http://fizika.org/ilwcro/results/newsrelease.html

Sources for Whistler Receivers - I get quite a few requests for information on commercially made whistler receivers and kits. Here are the current sources that I know about.

It appears that the popular WR-3 is available in its latest version from Steve McGreevy. The circuit has been re-designed for more sensitivity and lower noise, and the filters have been upgraded. You can order it from the website at http://www.qnet.com/~vlfradio/wr3.htm, or contact S. P. McGreevy Productions; P.O. Box 928; Lone Pine, CA 93545-0928 USA.

The INSPIRE VLF-2 is available assembled or in kit form on the web at http://image.gsfc.nasa.gov/poetry/inspire/orderform.html, or from Bill Pine, Science; Chaffey High School; 1245 N. Euclid Avenue; Ontario, CA 91762 USA.

For information on the KIWA Earth Monitor, go to http://kiwa.com/ethmon.html. It is available from Kiwa Electronics; 612 South 14th Avenue; Yakima, WA 98902 USA.

The L500 E-Field receiver and the L600S loop receiver are available from LF Engineering at http://www.lfengineering.com/base.html. They can be contacted at LF Engineering Co.; 17 Jeffry Road; East Haven, CT 06513.

If anyone has any other sources of receivers, let me know and I'll be happy to publish them next month.

Your Much Appreciated Correspondence

•**Dave Laida, Delta Lake, NY. (laida@nystec.com)** The night of Jan 27 was warm enough to spend time outdoors listening and I was rewarded with loud musical tweeks and weak Russian navaid signals about 2400 UTC at FN23. To counter intense power line and LORAN-C overloading I've had to sacrifice receiving system sensitivity and concentrate on maximizing dynamic range. I'm now experimenting with a 39-inch vertical whip in flat clear terrain with its tip only six feet above ground level and a home built preamp using the Burhans noiseless feedback concept. Not much gain but the improved linearity permits distinctly hearing weaker signals adjacent to powerful interference on a Radio Shack 32-2040 amplified speaker.