Natural Radio

News, Comments and Letters About Natural Radio

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VLF Emissions As promised a couple of months ago, we will again revisit Robert Helliwell's 1965 book, *Whistlers and Related Ionospheric Phenomenon,* this time relating to VLF Emissions. We will also explore some of the newer research into the topic that has been ongoing in the almost 40 years since the book was published.

Research has been a bit more difficult than I anticipated. No books have been written on Natural radio since Helliwell's above mentioned book. Most new information is contained in highly technical papers and more often than not, the Natural Radio aspect of the phenomenon takes a back seat to other issues. Since satellites can measure ionospheric and magnetospheric phenomenon at the point they are happening, there is less dependence on reception of ULF and VLF signals on Earth in the research of geomagnetic phenomenon. Nevertheless, much highly specialized research is being done and scientists are better able to measure the phenomenon than ever before.

It seems that Natural Radio listeners tend to spend most of their time chasing whistlers and give chorus and other discrete emissions just passing mention. VLF emissions are those other strange signals we hear on our radios apart from sferics, tweeks and whistlers.

Unlike sferics, tweeks and whistlers that originate on the surface of the earth from lightning discharges, VLF emissions originate in the ionosphere and magnetosphere and are highly dependent on the interaction between the earth and the sun via the solar wind and Coronal Mass Ejections.

Helliwell did a great job of laying the groundwork for future research, and classified these emissions as follows:

Hiss - Hiss is noise that resembles band limited thermal noise and may either be steady or varying and of different spectral distributions.

Discrete Emissions -- Discrete Emissions are transient emissions of a few seconds or less such as risers, falling tones, hooks or various combinations thereof. They can be pure tones or diffuse (swishy sounding).

Periodic Emissions – Periodic Emissions are a sequence of discrete events or clusters of discrete events that have regular spacing. The spacing usually is between two and six seconds. If the period of spacing varies with the frequency of the emissions, they are said to be dispersive. If there is little or no variation in spacing with frequency, the emissions are said to be non-dispersive.

Chorus -- Chorus is a sequence of closely spaced, discrete events that often overlap in time. Chorus may sound like a flock of birds or a pond full of frogs in the spring. One of the most common forms of chorus consists of many rising tones in the 1 kHz. to 5 kHz. range. Sometimes a continuum of background hiss is present. Chorus frequently is composed of

different sets of periodic emissions superimposed over each other. Chorus was formerly referred to as “Dawn Chorus”.

Quasi-Periodic Emissions -- These consist of repeated burst of signal of relatively long period, in which each burst my consist of a number of discrete events, periodic emissions or chorus. The period between bursts is on the order of tens of seconds and is relatively irregular as compared to periodic emissions.

Triggered Emissions -- This is any emission that appears to have been triggered or initiated by another event. Triggering sources might include whistlers, discrete emissions and signals from VLF transmitters.

In general, it was determined that the amplitude range of discrete emissions was similar to that of whistlers. It was also established early on and documented by Helliwell that in general, VLF emissions showed a positive correlation with increased geomagnetic activity. Incidence of VLF emissions as related to Kp reaches a peak at a certain value of Kp that decreases with latitude. At mid-latitudes in the US, the peak occurs at a Kp of about six, while in Northern Canada and Alaska the peak occurs at a Kp of 1 – 3.

VLF Emissions, like whistlers, are more common at middle and high latitudes. They tend to be somewhat localized events that may be heard simultaneously up to several hundred km. apart. Correlation is considerably reduced at distances over 1000 km. There is, however, a correlation in intensity of events heard at receiver sites of more than several thousand km apart.

Besides correlation with geomagnetic activity, there is an association of VLF activity and auroral phenomenon. Hiss is associated with arc and band auroras.

More Recent Research – At the time *Whistlers and Related Ionospheric Phenomenon* was written in 1965 not much was known about the sources of VLF emissions other than that they probably originated in the ionosphere or magnetosphere. Since that time, probing the ionosphere and magnetosphere with balloons and satellites has provided a much better understanding of the sources and properties of these emissions.

In reading some of the current articles, it appears that in most cases, VLF emissions are divided into the broad categories of chorus and hiss. Hiss is defined as uncoherent band-limited noise and chorus is what Helliwell defined as chorus, plus its component parts like risers, fallers, hooks and other discrete emissions.

Current research has shown that chorus is produced in the magnetosphere within a few degrees of the geomagnetic equator. It then propagates in whistler mode along the earth’s field lines toward the poles where at some point, it enters the earth-ionosphere cavity and travels to the listener.

VLF emissions such as chorus and ELF hiss are often observed after major substorm activity in the morning to noon hours. Chorus is often heard from midnight to dawn at the very beginning of a substorm.

Chorus emissions have been observed to be turned on and off by sudden fluctuations in the solar wind dynamic pressure and southward turnings of the Interplanetary Magnetic Field (IMF).

It has also been discovered that ULF pulsations may trigger chorus and are probably responsible for what we hear as quasi-periodic emissions. Pc3 and Pc4 pulsations were shown to affect chorus back in 1980. Another current study showed a strong correlation between chorus and Pc5 pulsations.

Listening To VLF Emissions – If you are new to Natural Radio listening, chorus is probably a better target than whistlers. Personally, I hear chorus more often than whistlers. There are several reasons for this. First of all, chorus is fairly predictable. If the Kp is above 5, it is very likely that chorus can be heard in the early morning hours. Secondly, chorus tends to peak after dawn and often can be heard into the late morning hours. For those of us in populated areas, there are few quiet sites available before dawn without scheduling a camping trip.

As we come off the peak of the solar cycle we are heading into what is usually the peak of geomagnetic activity. Keep your eyes on the Kp index either via the Internet or by listening to WWV at 18 minutes past the hour. If the Kp is above 5, head for your quiet site after the sun comes up and prepare to hear some chorus.

References – This article was meant to be an update in the simplest terms on VLF emissions and not a scholarly paper. Information came from Robert Helliwell's 1965 book *Whistlers and Related Ionospheric Phenomenon*, published by Stanford University Press and now out of print and from a variety of technical research papers found on the Web. Searching the Web with the term "VLF Chorus" will point you to many of the scientific papers that describe current research on the origins of VLF Emissions and how they relate to other geomagnetic phenomenon.

Scientific papers start by presupposing that you are familiar with previous research and terminology, and thus can be very difficult to comprehend. An excellent reference that will help you understand much of the terminology used in these papers is the online Space Physics Textbook published by the University of Oulu in Finland. The website address is http://www.oulu.fi/~spaceweb/textbook/