Natural Radio

News, Comments and Letters About Natural Radio

March 2006

We've been enjoying an unusually balmy winter with record temperatures soaring to almost 60. Friday night brought us back to reality with an overnight temperature plummeting to -15 degrees. But, I am consoled by the fact that the construction chaos I have endured for the past year behind my office has now been replaced by a heated parking garage.

The evening workshop time I had hoped for was pre-empted by a bad hot water relief valve, an electronic furnace igniter that has an undiscoverable bad solder joint and finally a pressure tank on our well that failed catastrophically. This weekend, an automatic Windows update wiped out all the user data on my laptop. Hopefully, with the delayed completion of this article, this phase of technological malfunction is over.

Fortunately, the equipment problems only seem to be occurring along a field line passing through my house. The Cassini Satellite is working well, and has been tracking a large lightning producing storm on Saturn. The latest version of Spectrum Lab is awesome. If you are not familiar with Spec Lab, it is a freeware spectrum analysis and audio signal processing and analysis program. In between fixing things, I did get to spend some time with it this month and have also been following the Spec Lab discussion thread on Yahoo that was mentioned here last month. I'll be writing an article on using Spectrum Lab for Natural Radio applications in the next few months after I do a bit more playing with its massive list of features.

Also, as mentioned last month, a reprint Prof. Robert Helliwell's book *Whistler's and Related Ionospheric Phenomena* is now available on Amazon. After revisiting the book, and discovering that I didn't understand many of the terms being discussed, I decided to do some research and share the results here. Starting this month I'll be writing an occasional series looking into some of the science behind whistlers and other emissions in the Magnetosphere. The focus will be on background information and explanations that will make the reading of Helliwell's book a little easier for those of us that have either forgotten or never had a field theory course.

2007 To Be International Heliospheric Year – In 1957, I was in fourth grade and being interested in science even at that tender young age, I remember reading articles and hearing about the International Geophysical Year in science class. Many years later I came to appreciate the studies begun and accomplished in that year, since much of our knowledge of Natural Radio and Space Weather came from that research.

Next year is the 50th anniversary of the IGY, so it has been proposed to hold an International Heliospheric year in 2007 that will focus on the problem of solar variation effects on Earth. NASA has proposed 6 objectives of study:

> The objective of the IHY is to discover the physical mechanisms at work which couple the atmosphere of the Earth to events that drive them from the heliosphere. It has been obvious for some time that events on the Sun can affect geospace, and even the Earth's

climate. The systematic global study of this connection is to be the central theme of the IHY. In view of these aims, we propose the following objectives for the IHY.

1. Develop the basic science of heliophysics through cross-disciplinary studies of universal processes.

2. Determine the response of terrestrial and planetary magnetospheres and atmospheres to external drivers.

3. Promote research on the Sun-heliosphere system outward to the local interstellar medium - the new frontier.

4. Foster international scientific cooperation in the study of heliophysical phenomena now and in the future.

5. Preserve the history and legacy of the IGY on its 50th Anniversary.

6. Communicate unique IHY results to the scientific community and the general public.

It appears that there will be opportunities for amateur observation and I will keep you posted as I find out what's available.

Large Lightning Storm Observed on Saturn – The University of Iowa is home to the Radio and Plasma Wave Science Investigation (RPWS) that is aboard the Cassini spacecraft in orbit around Saturn. Cassini has detected a massive lightning storm on the planet. UI Professor Donald Gurnett, principal investigator for the project, stated: "It is clear that this is the strongest lightning activity that we've seen yet with Cassini since it has arrived at Saturn. In fact, the flash rate even exceeds the rate observed by Voyager 1 back in 1980 and the intensities are at least as large, if not larger." The Iowa built RPWS instrument detects lightning through a wide-band receiver.

Lightning storms on Saturn seem to be quite different than terrestrial ones, and the origin of such storms is unknown. Cassini has shown that such storms can emerge suddenly and last for several weeks to a month. The current storm is larger than the continental United States and the lighting packs a wallop 1000 times greater than a typical earthly strike.

A Little Bit of Plasma Physics, Part I – In researching different Natural Radio related topics for this journal and just for my own education I find that most of the information available is either in academic journals or doctoral dissertations. This means that it is highly technical and assumes a solid background in math and plasma physics.

What I'd like to attempt in this series is to try to simply define some of the terms that you are likely to come upon in your readings and also try to explore the current theories and understandings of whistlers and other ionospheric phenomena with minimal mathematics.

Let's begin by realizing that just like earthly weather, there are a large number of highly variable factors that influence the generation and propagation of plasma waves and the behavior of particles in the magnetosphere. To quote Dr. James Greene of NASA, "Even after more than a decade of spacecraft observations of magnetospheric plasma waves, we understand very little about how they are generated." Despite the mystery and complexity, there is a lot that we do know, so let's begin with that.

One of the things studied in Plasma Physics is the earth's magnetosphere and the behavior of the particles and waves contained within it. Despite the implication of higher math, we might want to know a little more about Plasma Physics because most Natural Radio signals originate as plasma waves in the magnetosphere.

Plasma is a very hot ionized gas -- that is, electrons have been stripped of atoms leaving negatively charged electrons and positively charged ions. Because it is ionized, it is conductive.

In the ionosphere, the major cause of ionization is ultraviolet energy from the sun. Anyone who does any radio listening is well aware of the differences between night and day propagation of radio waves, which is due to the ionization that is happening when the ionosphere is in sunlight and the recombination of atoms and loss of ionization when the ionosphere is in darkness.

In your reading, you are sure to hear about hot plasmas and cold plasmas. In most cases, this probably has less to do with physical temperature of the plasma and more to do with the mathematical model. The most complex mathematical model for studying plasma is the **hot plasma model**. In this model all the variables are taken into account and thus the equations are most complex.

In the **warm plasma model**, the energy equation is included, but the term involving the heat flux vector is neglected, simplifying the calculations.

The **cold plasma model** is the simplest, and it contains only the equations of conservations of mass and momentum -- thus the cold plasma model assumes a zero plasma temperature. This model can be used in the study of small amplitude electromagnetic waves propagating in the plasmas.

Plasma out in free space is ***isotropic***, that is, its characteristics are the same in all directions. Plasma in the near-earth environment is ***anisotropic*** because it is subject to the earth's magnetic field. That is, the characteristics of the plasma are different in a direction parallel to the magnetic field lines than they are perpendicular to the field.

Plasma in the magnetosphere is subject to all kinds of perturbations. Because plasma is fluid-like with free electrons and ions, the disturbances cause these free electrons to oscillate about their equilibrium positions. If we could measure the electric fields in this perturbed plasma, we would see a resonance at a particular frequency, called the electron plasma frequency or simply plasma frequency. This frequency is proportional to the square root of the electron density of the plasma. Thus, by measuring this frequency, we can determine the electron density of the plasma. The plasma frequency is also known as the Langmuir frequency.

This is one of many characteristic frequencies of plasma. For our purposes, another important characteristic frequency of plasma is called the electron cyclotron frequency. If the plasma is embedded in a quasi-static magnetic field, the charged particles are accelerated in a direction perpendicular to the field. This causes them to move in spiral motion around the field lines.

A practical example of this motion is the Magnetron in our microwave ovens. Electrons are injected into the cavity of the magnetron, which is situated between the poles of a powerful magnet. The electrons spiral around the field lines of the magnet and oscillate at microwave frequencies. The basic frequency of rotation of an electron about a magnetic field is proportional to the strength of the magnetic field. This frequency is the electron cyclotron frequency.

In the case of the magnetosphere, the magnetic field of the earth is the field and the electrons are the free electrons in the magnetosphere. The magnetic field of the earth is magnitudes less in strength than that of the magnet in our magnetron, and thus the earth's electron cyclotron frequency is well below the microwave region, typically around 900 kHz over the geomagnetic equator.

As in our magnetron example, particles spiraling in magnetic fields will give off electromagnetic waves and the frequency of the emitted waves is usually related to the strength of the magnetic field. This kind of process and similar ones are responsible for the generation of a large variety of electromagnetic and electrostatic waves in the Earth's magnetosphere. These waves are called plasma waves and can propagate from one point in the plasma to another without net motion of the plasma.

Plasma waves have frequencies that are generally at or below the various characteristics of the plasma, such as the plasma frequency or the electron gyrofrequency. In general, such waves do not propagate outside of the plasma and are strongly influenced by the magnetized plasma when they do propagate.

The magnetosphere traps many of these waves such as ion cyclotron and electron whistlers, ELF and VLF hiss, and chorus. Other magnetospheric electromagnetic waves can travel out of the magnetosphere such as the non-thermal continuum radiation and auroral kilometric radiation. These types of emissions are readily observed in interplanetary space.

A plasma wave is said to be propagating in Whistler mode when it meets the following conditions:

- It propagates parallel to the magnetic field in which the plasma is embedded.
- Its frequency is less than that of the electron cyclotron frequency.
- The wave is circularly polarized, rotating about the magnetic field in the same sense as the electron gyromotion.

Whistler mode waves have phase velocities which nearly match the motion of electrons around the magnetic field lines. They can thus interact strongly with the electrons and result in a scattering process which would dump electrons otherwise trapped in the Earth's Van Allen radiation belts into the atmosphere causing aurora displays and other effects. The whistler is also known as the electron cyclotron wave.

Unlike plasma waves, radio waves can propagate more or less freely through the plasma. Ordinary radio waves propagate only at frequencies higher than the electron plasma frequency. At frequencies below the plasma frequency, the plasma is opaque to electromagnetic radiation. At the lower frequencies, the electrons interact with the radio waves and vibrate and absorb the energy of the electromagnetic wave. This property is readily observable in the ionosphere. Higher frequency waves pass through the ionosphere -- for them it is transparent. Depending on frequency, lower frequency waves are either absorbed or refracted.

In the next installment we'll look into some of the factors that affect whistler generation and propagation.