Development of Natural Radio ELF / VLF Receiver

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Abstract

Extremely Low Frequency (ELF~3 Hz–3 KHz) and Very Low Frequency (VLF~3 KHz-30 KHz) are allocated at the lowest portions of frequency spectrum. The advantages of the ELF/VLF radio waves, which was a significant reason for the research into it, was ELF/VLF wave's ability to propagate globally without excessive attenuation. ELF / VLF waves are important not only as communication tools, but also as remote diagnostic probes to determine the characteristics of the Earth such as Earth's curst, the Ionosphere and Magnetosphere. The intension of this project is to study and investigate the naturally induced ELF/VLF radio waves, especially Lightning-Induced electromagnetic emission due to the locality of Malaysia which includes in the regions of highly tabulated lightning activities.

Applications

1. ELF/VLF waves have been extensively used for navigation as worldwide telegraphy to ships and submarines, worldwide communication, mine and subterranean communication. ELF wave has the ability to penetrate ocean depths to several tens of meters with little signal loss. This ability allow submarine to be operated well below the immediate surface and enhances submarines survivability by making detection more difficult. Meanwhile, VLF communication system work as the communication commitments of the Navy now cover the face of the Earth.
2. Scientists and researchers are interested to the characteristics of ELF/VLF waves and utilize ELF/VLF waves to probe D-regions of the Ionosphere and the Magnetospheric probing as well as the investigation of Lightning-Induced Electrons Perturbation (LEP) which creates ELF/VLF whistlers mode waves and others "Earth's Song"-Natural ELF/VLF waves. There are high power HF ionospheric heating facilities at the Arecibo, HIPAS and HAARP Observatories have been used in a number of campaigns to modulate ionospheric current system at ELF / VLF frequencies in order to produce ELF / VLF waves *(Ferraro et al., 1982)*

Sources of ELF and VLF Radio Waves

ELF and VLF transient signals and noise are generated by various natural and artificial phenomena.

1. **Natural Sources** of ELF and VLF Radio Waves

   ~ Natural origin include the familiar lightning discharges from thunderstorms, volcanic eruptions, dust storms and tornadoes. At high latitudes, noise emissions generated by charged particles (polar chorus, broadband auroral hiss), occasionally dominates all the lightning generated waves in polar region. However, on a global basis, by far the most significant source of wave at ELF/VLF is that generated by lightning discharges.

2. **Man Made Sources** of ELF and VLF Radio Waves

   ~ Generation processes of "Wireless" antennas with amplitude modulated HF heating are among a number of different schemes, employing the interaction of HF radio waves in the ionosphere. It have been proposed for the generation of ELF/ VLF signals. Besides, in the 1950s and 1960s nuclear explosions due to a large number of nuclear tests from below the sea surface to high in the atmosphere have been discovered strong impulsive VLF signals (*Barr et al., 2000*).

Theory of ELF and VLF wave Propagation

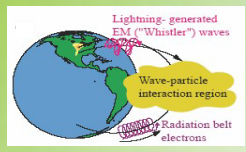
1. Electromagnetic waves reflect when incident upon conducting boundaries and can be guided along partially enclosed conducting structures. At ELF / VLF, the surface of the Earth and the lower edge of the ionosphere act as good electrical conductors which form the Earth-ionosphere waveguide. Lightning activity happen in the Earth-ionosphere waveguide which is composed by two parts: first thin channel growing from ground to cloud. Secondly, a bigger channel called "return stroke" goes from the cloud to ground.
2. The return stroke radiates the bigger part of the signals which able to listen in receivers called "Spherics", "Tweeks", travels in the Earth-Ionosphere waveguide and a fraction of the energy radiated by a lightning discharge which escape into the magnetosphere and propagates as whistlers-mode wave, "Whistlers".

Natural Radio ELF / VLF Receiver Station

1. Octagonal Loop Antenna
2. Preamplifier
3. Amplifier
4. PC Soundcard Data Acquisition and Analysis

Lightning-Induced Electron Precipitation Events (LEP)

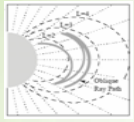
The physical mechanism for LEP VLF events involves a process of magnetospheric wave-particle interaction, through a process known as gyroresonance. It interacts with and changes the pitch angle of trapped radiation belt electrons, causing those close to the loss cone to precipitate into the lower ionosphere



Ducted and Oblique Whistler wave propagation paths

Both "Ducted" and "nonducted" whistler waves respectively propagate along and at a varying angle (i.e., obliquely) to the geomagnetic field lines and also introduce the process of gyroresonance (*Johnson, 2000*).

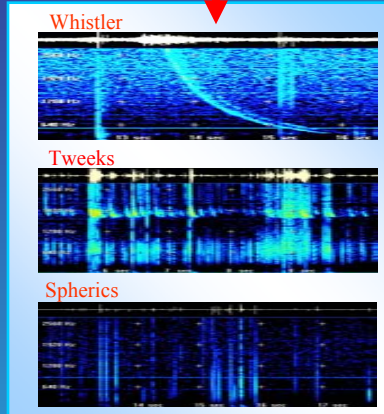
Example ray path of a whistler wave propagating along a duct of enhanced conductivity.



Example ray path of an obliquely propagating (nonducted) whistler wave.

Oblique-Whistler Precipitation

The discharge current from a lightning flash radiates impulsive electromagnetic wave energy in all directions. This impulsive wave energy spreads throughout the earth-ionosphere waveguide while a portion couples into and propagates obliquely throughout magnetosphere, suffering frequency-dependent spatial refraction and temporal dispersion to form the characteristic oblique whistler (*Lauben, 1998).*



Spectrogram Analysis

Conclusion

Lightning-induced natural radio waves (ELF / VLF) offer a vast of unexplored phenomenon to be discovered especially for equatorial naturally electromagnetic emission of the Earth where the documentations and observations are insufficient compare with the effort that have been carried out in the polar regions. The development of Natural Radio ELF / VLF Receiver is an early steps to enable the study of natural radio which require a long terms of exertion to determined the exact natural radio environment in the equatorial regions. Especially the whistler wave which travel in the magnetosphere and the effect of equatorial anomaly to the ELF/ VLF whistler waves ray path.

References

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