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Siple transmitter signals as
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the magnetosphere

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Natural very low frequency (VLF) whistlers from lightning propagate on magnetospheric field-aligned paths from hemisphere to hemisphere. A well established theory relates the observed frequency-time or dispersion characteristics of a whistler to the electron density along its path and to the path equatorial radius (e.g., Helliwell, 1965). This theory enables us to obtain much detailed information on the distribution and dynamic behavior of the magnetospheric plasma. The area of Siple and Eights stations possesses exceptional properties as a whistler-receiving location (e.g., high conjugate lightning rates, low local noise). For example, the data acquired there have provided much knowledge of the important geophysical boundary known as the plasmapause (Carpenter, 1966). At this field-aligned boundary, typically four earth radii distant at the equator, the plasma density may drop by from one to two orders of magnitude within a fraction of an earth's radius (Angerami and Carpenter, 1966). Figure 1 shows two equatorial profiles of electron density deduced from Siple whistlers. Dashed curves provide estimates of the general trends shown in the data. One example (circles) involves quiet magnetospheric conditions; the profile extends relatively smoothly to \( \approx 5.5 \) earth radii and the plasmapause is not defined. The other case (triangles) involves moderately disturbed conditions; the plasmapause is present near four earth radii, which is near the field lines connecting Siple, Antartica, and Roberval, Quebec (Canada).

What role can the Siple transmitter signals play as diagnostic probes of the magnetosphere? A study has been made of the circumstances of transmitter signal reception at Roberval. Travel time versus frequency characteristics of the Siple signals were compared to those of whistlers. Figure 2 shows frequency (1.5 to 3.5 kilohertz) versus time records of frequency ramps transmitted at Siple (above) and received \( \approx 3.2 \) seconds later at Roberval (below). The double ramp structure at Roberval (lower left) shows evidence of propagation on more than one path, while the curvature of the received ramps

References


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Figure 4. Roberval programs illustrating bands immediately the 5.950- and 5.360-transmitter frequency. The transmissions noted at 1152 UTC, Time (lower right).

Figure 5. Roberval programs illustrating variable nature of growth and amplitude during a single frequency ramps second pulse. Each shows the same response format.
Figure 1. Magnetograms showing the changes in the magnetic field strength during solar cycle 23. The horizontal bar represents the period of time when the field strength was above a certain threshold, indicating a solar storm event. The vertical axis shows the magnetic field strength in nanoTeslas (nT).

Figure 2. The solar wind speed and solar magnetic field strength plotted against time. The black line represents the solar wind speed, while the red line represents the solar magnetic field strength. Both parameters show significant variations throughout the year, with peaks during solar maximum.

Figure 3. A histogram showing the distribution of peak solar wind speeds observed during solar years 2000-2010. The x-axis represents the speed range, while the y-axis represents the number of occurrences. The data shows a bimodal distribution with peaks around 400 and 800 km/s.

Figure 4. A scatter plot showing the relationship between solar wind speed and solar magnetic field strength. Each point represents a single observation, with the color intensity indicating the strength of the solar magnetic field. The plot reveals a positive correlation between the two parameters, with faster solar wind speeds typically associated with stronger magnetic fields.

Figure 5. A series of images showing solar coronal holes, which are regions of the sun's surface with lower magnetic field strength and higher solar wind speed. The images are taken from different angles and times, showing the dynamic nature of these features.

Figure 6. A time-lapse video showing the evolution of a solar prominence, a temporary outburst of plasma and magnetic field. The video illustrates the dynamic and transient nature of solar phenomena, with rapid changes in the prominence's appearance and structure.
The path concentration should facilitate experiments in which path location is of particular importance, such as the search (using balloon-borne ray counters, riometers, etc.) for the effects of induced precipitation of energetic electrons in the lower atmosphere. Further, magnetospheric phenomena of interest tend to move in a form that permits the various important states of the signal to be scanned through sufficiently long-term observations near given field lines; this is illustrated in figure 1. In one case (circles) the signal probes conditions well inside the plasmapause, while in the other case it probes the region of steep plasmapause density gradients.

The transmitter signals have been used to advance a recent (June and July 1975) test of a VLF section finding on signals emerging from the ionosphere in the vicinity of Roberval. Participants in the test included Japan, the United Kingdom, and the United States benefited from the availability of signals of low frequency in a known signal format, propagating within an expected north-south range.

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Satellite observations of nonducted signals from the Siple transmitter

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In a circular region with a radius of about 500 kilometers, a substantial portion of the energy radiated by the Siple transmitter enters the ionosphere and propagates into the magnetosphere in the whistler mode. The path of propagation in the magnetosphere may be either ducted or nonducted. Ducted signals follow geomagnetic field-aligned paths and may emerge from the ionosphere and be observed at ground stations (Helliwell, 1965). Nonducted waves follow more complicated paths: they tend to remain above the lower boundary of the ionosphere, and are not usually observed on the ground (Smith and Angerami, 1968).

The properties of ducted signals are by far the best understood; most of our knowledge about whistlers, very low frequency (VLF) emissions, and wave-particle interactions in the magnetosphere derives from their study. The nonducted mode nonetheless is important; about 90 percent of the energy radiated by a VLF ground transmitter will propagate through the magnetosphere in this mode.

It generally can be expected that the nonducted waves from the Siple transmitter will interact with energetic particles in the magnetosphere and will produce VLF emissions and particle scattering in the same manner as ducted waves. The nonducted