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High altitude satellite observations of signals from the Siple transmitter

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Satellite observations have been an important component of recent very-low-frequency (VLF) wave-injection experiments carried out with the aid of the Siple Station (76°S 84°W) VLF transmitter. The goal of these experiments is to study interactions in the magnetosphere between coherent VLF waves and energetic particles, and in particular to study the physics of the VLF emission generation process. The coherent waves involved in this study are injected into the magnetosphere by the Siple Station VLF transmitter, while VLF wave and energetic particle measurements are obtained on one or more spacecraft. Wave observations are also carried out at a number of ground stations, such as that at Roberval, Canada (Helliwell and Katsufrakis 1974).

Although ground-based measurements can determine a number of important features of the interactions involving ducted waves, most of the waves injected by the Siple Station transmitter propagate in the magnetosphere in a nonducted mode, and although these waves are capable of strong interaction with energetic particles in the magnetosphere, the output of these interactions is not observable on the ground because the nonducted waves generally cannot penetrate the lower ionosphere. Thus the only means of observing the output of wave-particle interactions involving nonducted waves is through the use of satellites or rockets.

In the past year, two high-altitude satellites have obtained measurements in the magnetosphere during Siple Station VLF wave-injection experiments, namely the ISEE–1 and the EXOS–B spacecraft. Because of differing orbits and instrumentation, each spacecraft has played a unique role in supporting the Siple Station investigations.

The high-altitude ISEE–1 spacecraft has been uniquely valuable in obtaining measurements of Siple transmitter signals outside the plasmasphere in the low plasma density region where strong interactions with high-energy electrons (energy greater than 40 kiloelectronvolts) takes place (Bell, Inan, and Helliwell in press). Emissions triggered by Siple transmitter signals outside the plasmasphere are shown in figure 1; they are representative of an approximately 15-minute period during which Siple signals were observed on ISEE–1. As shown in figure 1, the transmitter pulses were occasionally observed to trigger very intense noise bursts. The upper panel shows a 5.8 kilohertz pulse (near the 5-second mark) triggering a very intense burst of rising emissions. Subsequently a second, less intense noise burst is triggered by a 5.6 kilohertz pulse (near the 9–second mark). The lower panel shows the format of the Siple transmitter signals as actually transmitted. In general the triggering of VLF emissions was associated only with pulses with frequencies near 5.6 kilohertz. This frequency selectivity of the emission process is a common feature of wave-particle interactions in the magnetosphere.

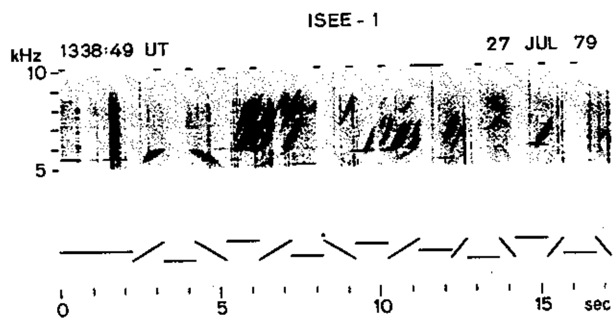

Figure 1. ISEE–1 satellite observations of Siple Station transmitter pulses triggering VLF emissions.

During campaigns in the periods July to September 1979 and December 1979 to January 1980, experimenters from Stanford, Kyoto, and Tokyo Universities conducted joint wave-injection experiments using the Siple Station VLF transmitter and the Japanese high-altitude satellite EXOS–B. During these experiments the properties of the transmitter pulses and associated emissions were measured on the satellite by a VLF receiver (Matsumoto, Miyatake, Tsuruda, Morioka, Ohtsu, Oya, and Kimura in press) while the properties of the interacting energetic electrons in the range 4 electronvolts to 6.9 kiloelectronvolts were measured by an onboard energetic particle experiment (Kubo, Mukai, and Kawashima in press). Results of these joint studies will be reported in the near future.

An example of the VLF wave data acquired on EXOS–B during the joint campaign is shown in figure 2. The upper panel shows strong emissions triggered by Siple transmitter pulses near 5 kilohertz. The second panel shows

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the actual transmitter format. The third panel shows strong emissions and a hiss-like noise burst being triggered by a long-duration transmitter pulse. The fourth panel shows the actual transmitted format appropriate to panel three.

The joint Siple Station/EXOS-B experiments are noteworthy in that they represent the first successful attempt to obtain simultanoous VLF wave and energetic particle measurements on a high-altitude satellite located near the wave-particle interaction region during wave-injection experiments. It is precisely this type of simultaneous wave and particle data which is necessary to understand the mechanisms through which VLF waves and energetic particles interact in the magnetosphere.

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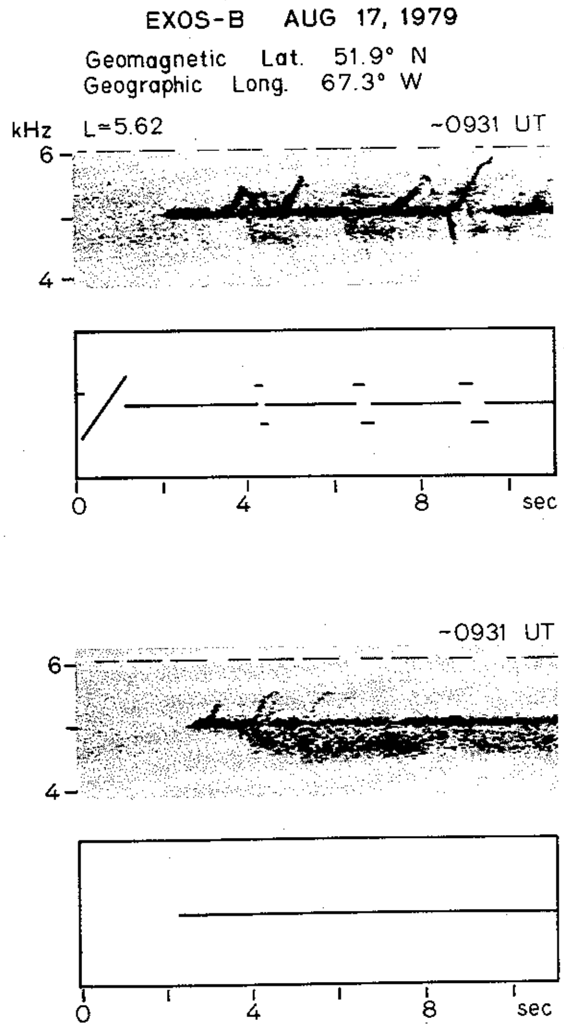

Figure 2. EXOS-B satellite observations of Siple Station transmitter pulses triggering VLF emissions.

Further evidence of wave-particle interaction in the magnetosphere

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Sinusoidal oscillations of the Earth's magnetic field, near 1 hertz in frequency, are often observed at Siple Station. These oscillations are thought to result from a cyclotron resonant interaction of hydromagnetic waves with protons in the magnetosphere (Gendrin 1975). Similar waves have been occasionally observed in the magnetosphere with satellite borne detectors (Taylor, Parady, and Cahill 1975). Some of these magnetosphere wave events were correlated with observations of enhanced proton fluxes (Taylor and Lyons 1976). Recently we observed indirect evidence of wave particle interactions by simultaneous observation at Siple of periodic modulations of 1 hertz fluctuations (pearls) and of auroral light intensity (Mende, Arnoldy, Cahill, Doolittle, Armstrong, and Fraser-Smith 1980). In the single case reported the observations agree with a model interaction between protons and waves only if the protons are more than 20° latitude from the equator. Helium ions 15° from the equator can also interact with the waves to