VLFs and the Magnetosphere

A process of wave interaction in the magnetosphere can amplify very low frequencies.

by Roger Allan

Part of the SEEP experiment carried aboard the S 81-1 satellite. Circular objects in the foreground are thermal radiators, used as part of the cooling system for the electron sensors which must operate at low temperatures for best sensitivities.

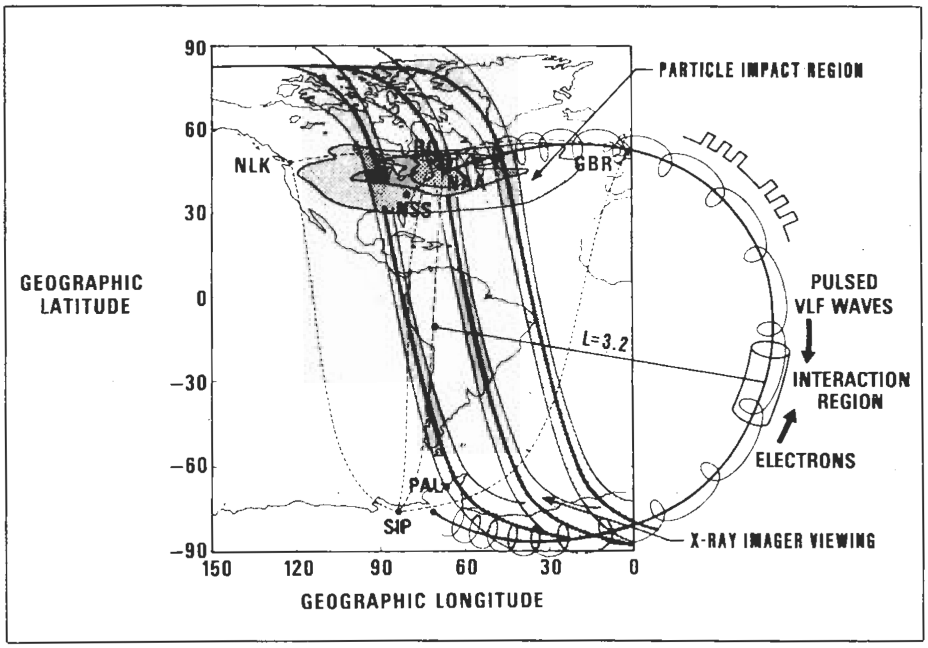
THE PROCESS of dumping electrons from the magnetosphere into the ionosphere goes on all the time and is a mechanism that helps maintain the equilibrium of the radiation belts, particularly the Van Allen belts, which surround the earth. The dumping process is due to natural processes and transmitted waves from the ground. Very often, high-power transmitters induce over half of the wave energy that exists in the magnetosphere. This process, known as field/effect/wave interaction results in the deflection of free electrons from the magnetosphere down into the ionosphere in a process identical to that caused by sunspot activity. When the freed electrons enter the ionosphere they create a miniature aurora borealis — small light emissions — that can be detected. In addition, it is felt that X-rays are released which should be discernable.

For some years, scientists have believed theoretical calculations which indicated that such ground based generation of Very Low Frequency (VLF) radio waves could result in these waves not only being transmitted thousands of kilometers but also amplified by the dumping process.

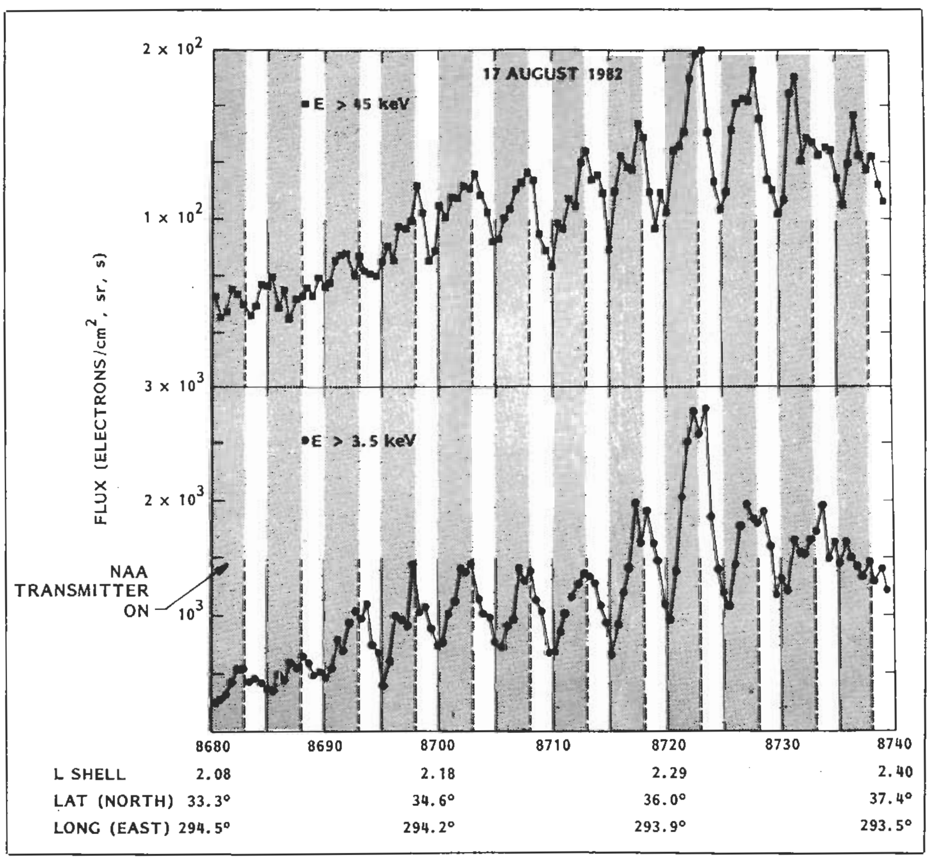
Acting under the sponsorship of the U.S. Office of Naval Research, Lockheed Palo Alto Research Labortory and Stanford University recently released the results of an experiment, known as SEEP (Stimulated Emission of Energetic Particles), which indicates that such a process in fact takes place, and further, that the amplification produced by the dumping process increases power factors by between 1,000 and 10,000 times (30-40 db).

The discoveries of this research program could lead to the improvement of radio communication by using magnetic field lines to capture and amplify VLF radio waves by utilizing that very large volume of space surrounding the earth that up until now hasn't been fully explored for its communication potential. Further, it provides a basis for improved minimization of deleterious heavy sunspot activity throughout the world.

Essentially, the experiment used a 1-Mw U.S. Navy VLF transmitter at Cutler, Main, Annapolis, Maryland and Jim Creek, Washington (used to communicate with submarines), and a 4 kw transmitter operated by Stanford University for the National Science Foundation at Siple, Antarctica, along with detectors mounted on the S 81-1 satellite — part of the USAF Space Test Program. Further, other satellites, specifically the Dynamics Explorer 1 and the International Sun-Earth Explorer flying at a higher altitude than the S 81-1, also carried VLF receivers to measure the intensity, frequency and



Location of high-power VLF Transmitters used in the SEEP experiment, along with a schematic representation of the interaction between pulse-coded very low frequency waves and the electrons spiralling around a magnetic field line connecting the Earth's northern and southern hemispheres. The high-power transmitters were turned on when the satellite was traversing regions (shaded areas) through which the displaced electrons moved. The interaction region marked in the diagram is at an altitude of approximately 8,500 km.



Example of Modulated Electron Beams

modulation timing of the transmitted waves above the interaction region — with such data being recorded at Siple and Palmer Antarctica, and Roberval Quebec, to correlate the data.

The transmitters were modulated in ten different on-off patterns, and evidence was sought in the output of cooled silicon detectors on board the S 81-1 while it was in low orbit of approximately 250 kilometers while the satellite was passing under a region exposed to interactions initiated by one of the four ground stations. Analysis shows that, for example, using a 3-sec on, 2-sec off format results in a 32 db increase in power, the amplification being due to the magnetosphere.

In addition to the particle detectors, the S 81-1 also carried an airglow photometer and X-ray mapping spectrometer to record expected side effects resulting from collisions between the displaced electrons and the constituents of the atmosphere. No data was generated in this part of the experiment due to an apparent lack of sensistivity on the part of the equipment.

While the experiment was deemed a success, several questions remain, such as why amplification seems to occur only at certain times, and how the waves penetrate the ionosphere and enter the magnetosphere. These sorts of questions may be answered by two follow up experiments. The first, involving what was originally known as the Waves in Space Plasmas (WISP) instrument, now known as the RPDP (Particle Interactions Recoverable Plasma Diagnostic Package), is currently under development by the Centre for Research in Experimental Space Science (CRESS) at York University in Toronto. Expected to be launched on the Shuttle as part of the Spacelab 6 mission in 1986 or 87, it will be used to study the effect of radio waves in the frequency of 0.3 MHz to 30 MHz on the Earth's ionosphere and magnetosphere. A second experiment, also under development by CRESS for the same Spacelab 6 mission, known as the Energetic Ion Mass Spectrometer (EIMS), may also answer some of these questions. It will allow scientists from the Herzeberg Institute of Astrophysics in Ottawa to investigate the properties of charged ions and molecules in the earth's atmosphere. By taking advantage of the large weight carrying capacity of the Shuttle, EIMS will have a sensitivity and precision far superior to those of previous space-borne instruments. It will be used to measure the composition and energy distribution of ion species occurring naturally in the magnetosphere as well as tracer ions injected as a result of other NASA experiments. **ETI**