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Very-Low-Frequency Phenomena, 1965-1966

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Research using antarctic data during the past year has led to a number of important results. Of special interest is the fact that a Ph.D. thesis has been written at Stanford based almost entirely on antarctic data. This study, by J. J. Angerami, has been partially summarized in a recent article in the *Journal of Geophysical Research* entitled "Whistler Studies of the Plasmapause in the Magnetosphere—2; Equatorial Density and Total Tube Electron Content Near the Knee in Magnetospheric Ionization." Another point of interest is that the results described below on convective motions are in large part the result of work by a first-year graduate student, Keppler Stone. His work has provided the basis for a joint paper (with D. L. Carpenter) that was presented at the 1966 Belgrade Symposium on Solar-Terrestrial Physics.

Research on hydromagnetic motions in the magnetosphere. Until a recent whistler study at Stanford, there was no direct evidence of slow (order of 1 hour) motions of the magnetospheric plasma. Many predictions had been made as to the co-rotation of the inner magnetosphere with the Earth and the expected motions that would take place in the outer magnetosphere due to the interaction between the magnetosphere and the solar wind. The experimental methods that did exist depended upon ground-based magnetometer measurements and upon many inferences about the coupling between the ground observations, the ionosphere, the tubes of force, and the region at great heights. Through the whistler method and particularly through the uniquely extensive and clear data obtained at Eights and Byrd, there exists a way of looking directly at the slow motion of discrete whistler paths and thus, by inference, at the slow motions of the plasma transverse to the geomagnetic field.

The principal results of the recent study are as follows: 1) the inner plasmasphere * (to an equatorial radius of about 3.5-4R_E) approximately co-rotates with the Earth; 2) slow (order of 0.1R_E/hour) radial motions in the plasmasphere agree well with the known diurnal variation in the position of the plasmapause during the period 2400 LT to about 1700 LT. Thus the slow radial variations in the boundary of the plasmapause are identified in general with the gradual compression and expansion of the material inside, and not with erosion or accretion at the boundary; 3) rapid radial motions (order of 0.3R_E/hour) occur occasionally in the plasmasphere. These motions tend to be limited in duration to one or two hours and at least on one occasion appear to be associated with a polar substorm. The correlation records taken at Byrd and Eights Stations since 1963, although very important in themselves, take on new significance in light of the aforementioned. It appears likely that, for the first time, quantitative estimates of plasma drifts (and thus the associated electric fields) in the remote magnetosphere may now be added to the simultaneous measurements of phenomena near the feet of the associated field lines.

Study of the upper cutoff frequency of ducted whistlers in the magnetosphere. For a number of years, it has been known that whistlers frequently exhibit an abrupt high-frequency cutoff (> 10 db. over an interval less than 1 kc./s.). Since 1961, there have been a number of attempts to interrupt this cutoff as evidence of absorption of the whistler-wave energy by cyclotron interaction with electrons in the tail of the thermal distribution. The attempts to apply the theory of Landau damping to whistlers have been seriously impeded, however, by a lack of experimental investigation.

An initial study has recently been made using whistler examples recorded at Eights Station in 1963 and in 1965. Spectrographic records of the cutoff properties of more than 500 whistler components were examined for the period June-August 1963. These examples represented field-line paths with equatorial range of 3-5.5R_E. It was found that inside the plasmapause: 1) The ratio of whistler noise frequency to cutoff frequency (f_n/f_{co}) is to first order independent of time, magnetic activity, and path latitude. 2) For about 80 percent of the measured components, $0.70 < f_n/f_{co} < 0.80$. 3) The whistler wave frequently shows evidence of amplification above f_n, the effect being pronounced just below f_{co}. 4) Quasi-constant tones of ~200 cps. bandwidth and 0.05-1.0 sec. duration are frequently triggered at the cutoff. This is the most common form of noise triggered by whistlers inside the plasmapause. 5) Stimulation of magnetospheric noise by a low-power (~100 watts) Omega transmitter (10.2 kc./s.) has been observed only at the upper cutoff frequency of an observed whistler path. 6) For a diffusive-equilibrium model of the distribution of magnetospheric ionization, the ratio of f_{co} to f_{Hmin}, the equatorial gyrofrequency, is such that $0.47 < f_{co}/f_{Hmin} < 0.53$.

* The plasmasphere is the dense region inside the knee, or plasmapause; the plasmapause is typically observed near L = 4.

Reprinted from the September-October, 1966 *Antarctic Journal of the United States*

The theory of whistler propagation in ducts of enhanced ionization predicts a cutoff at $f_{co}/f_{Hmin} \sim 0.5$. Therefore, it is concluded that the sharp whistler cutoff is basically a ducting effect, and that there is an associated instability that may result in amplification of the whistler below f_{co} (thus accentuating the cutoff effect) and in triggering of noise tones near f_{co} both by whistlers and by low-power transmitters.

It appears that the whistler cutoff phenomenon is a fundamental aspect of propagation of whistlers through the magnetosphere, and that an understanding of stimulation of noise by low-power transmitters or by whistlers themselves must be understood in conjunction with the ducting effect.

Other Subjects

Knee effects observed on polar-orbiting satellites. A number of remarkable discoveries have been made about the knee effect as observed by polar-orbiting satellites. On the basis of extensive studies using Eights data from 1963, precise information on the position of the knee in 1963 was available. Alouette-I records from 1963 were then examined and it was found that an abrupt cutoff in occurrence of whistlers occurs as the satellite moves poleward through the position of the knee. In addition to the very high correlation between the plasmapause position and the cutoff in whistler rate, a highly correlated change was found in the background VLF noise observed on Alouette-I. Further studies of these noise changes and whistler cutoff effects on POGO data are being made.

Saucers. In many high-latitude (e.g., Byrd Station) recordings of various satellites, a heretofore unreported phenomenon has been observed in which a noise band decreases in frequency to a minimum, then rises again. The noise appears to have some relation to the lower hybrid resonance (LHR) and is never seen on the ground. A noise band with this characteristic spectrum has been termed a "saucer." Saucers appear to fall into two categories: one in which the duration is from 10 to 30 seconds or longer, and which is somewhat irregular, and another category (called "demi-tasse") with a duration of 1 to 3 seconds, with fairly pure tones, and a remarkable degree of geometric symmetry. Demi-tasses have principally been observed on Alouette-I, suggesting that the noise is electrostatic.

The evidence so far seems to suggest that saucers are a nonpropagating, spatially-varying phenomenon.

Impulsive VLF noise at high latitudes. Another type of noise observed in the satellite and not on the ground is quite impulsive in spectral form with frequencies of maximum intensity that fluctuate rapidly. These noises usually last several minutes and are observed at latitudes higher than those where saucers are observed.

VLF/LF hiss associated with aurora. During the 1965 winter at Byrd Station, noise with a continuum from 4 to 465 kc./s. was observed during auroral storms. The observations are being extended up to several megacycles during the 1966 austral winter.