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(Project D48-95-11-33)

A Reprint from

Journal of
Geophysical Research

VOLUME 68 DECEMBER 15, 1963 NUMBER 24

PUBLISHED BY
THE AMERICAN GEOPHYSICAL UNION

JOURNAL OF GEOPHYSICAL RESEARCH VOL. 68, NO. 24 DECEMBER 15, 1963

Letters

Very-Low-Frequency Noise Bands Observed by the Alouette 1 Satellite

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A surprising feature of the signals observed by the VLF receiver aboard the Alouette satellite is bands of noise that vary systematically with the position of the spacecraft in the geomagnetic field [*Barrington and Belrose*, 1963]. Because of the limited VLF schedule of this satellite, only a few observations of these noise bands are available, but these are adequate to reveal some interesting features of such noise.

Figure 1 shows spectrograms of segments of the VLF signals observed during a full sweep

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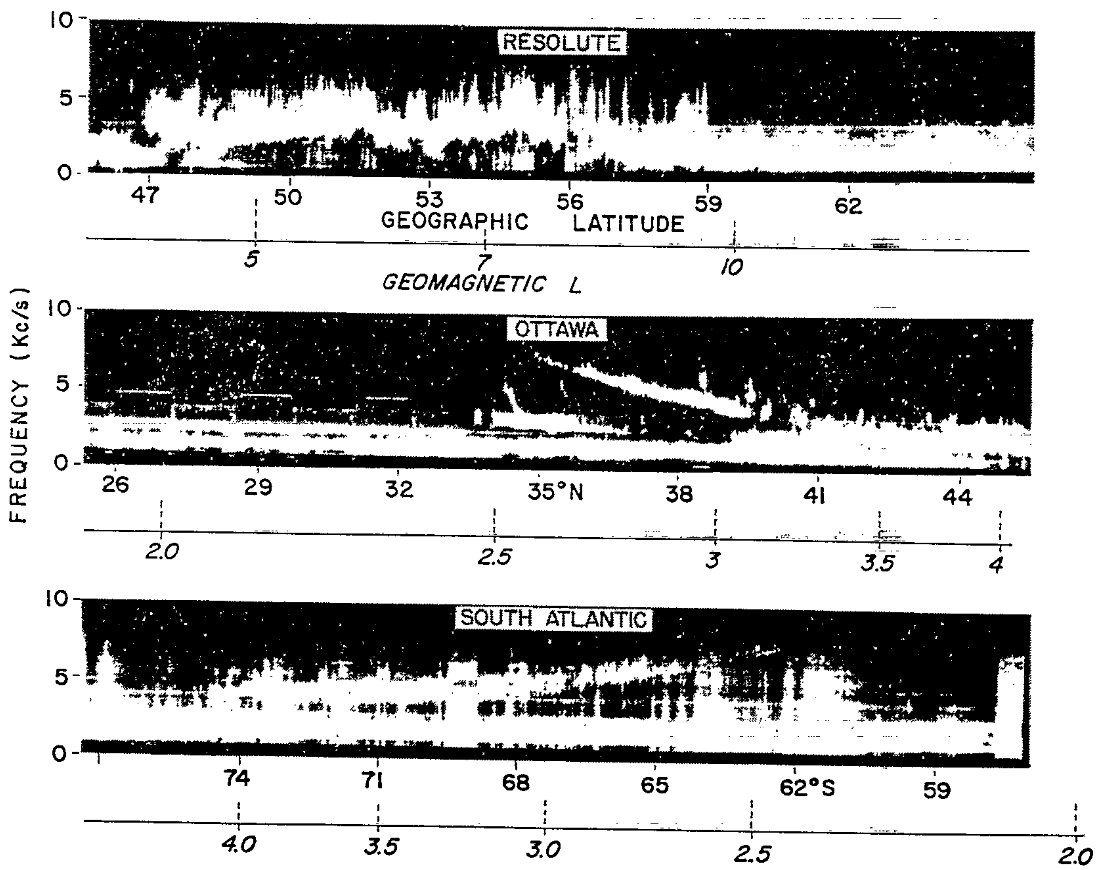

Fig. 1. Spectrogram of VLF ionospheric noise observed in Alouette 1 on January 31, 1963, 1057–1148 UT. The geographic longitude of the path of the satellite ranges from about 140°W at 80°N to about 10°W at 80°S and crosses the 75°W meridian near the equator. The captions on the three segments shown refer to the telemetry station where the data were recorded.

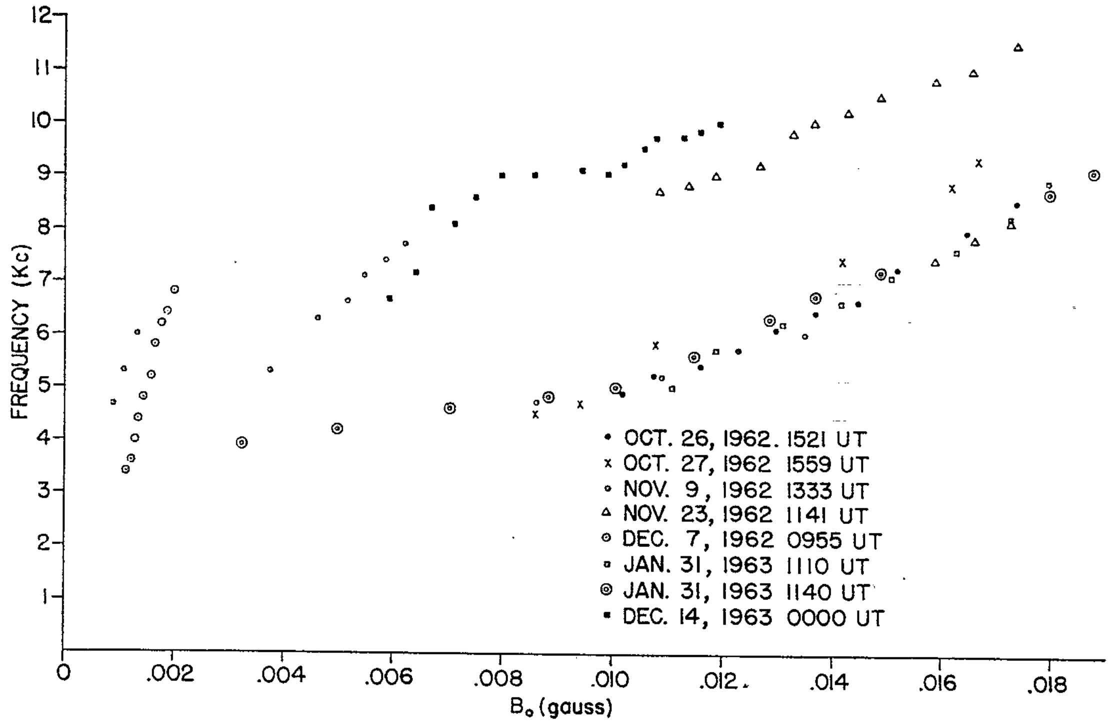

Fig. 2. Plots of the f_{low} (the lower edge of the noise band that shows systematic changes in spectral distribution with satellite latitude) versus B_0 (the minimum value of the strength of the earth's field on the field line at which the noise was observed) for several different events.

of the satellite from 80°N to 80°S geographic latitude. During this sweep a steady band of noise between 400 cps (the lower edge of the receivers passband) and 2.5 kc/s is observed when the vehicle is in a region where the magnetic parameter L is greater than 9. In the region where L lies between 9 and 4, the band becomes very erratic, both in amplitude and frequency. The limiting L values of this region correspond approximately with the values of L at the edge of the magnetosphere and at the horn of the outer Van Allen belt. At still lower L values the noise band becomes regular again and is observed as one or more quasi-constant bands even at the equator ($L_{min} \approx 1.1$). Near $L = 3.6$, a band of noise appears to 'rise out' of the upper of these noise bands, and, as the satellite moves to lower L values, the central frequency of this noise band increases and its bandwidth decreases until at $L \approx 2.6$ the noise band disappears. It is not seen again until the satellite has crossed the equator and again reached $L \approx 2.6$. At this point the noise reappears at approximately the same frequency as that at which it was last observed in the northern hemisphere and slowly increases in bandwidth and decreases in frequency as the satellite returns to higher L values. This behavior of the noise band, though not an every-day occurrence, has been observed on several days during a four-month period.

To a very high degree the noise observed at the same L value in the northern and southern hemispheres is the same in spite of the fact that the observations in the two hemispheres are separated by at least 30 minutes in time and several degrees in magnetic longitude and the local gyrofrequencies at the points of observation differ by as much as 30 per cent. These facts suggest that such noise bands must be due to conditions in the exosphere that are relatively constant and uniform over a large region. Although only limited information is available from ground stations, at the time of the observations of Figure 1 there seems to be no close correlation between the noise bands seen in the satellite and the signals observed on the ground. This lack of correlation may be due to absorption or total internal reflection of these noise signals in the ionosphere, the noise arising only in the immediate vicinity of the satellite, or to the fact that the ground stations can observe VLF signals that have emerged from the ionosphere over a large area.

In an effort to obtain more quantitative information on these noise bands, we scaled several of their features and plotted them as functions of different parameters of the geomagnetic field. It was found that to a good approximation the frequency of the lower edge of the noise band was inversely proportional to the cube of the L parameter at which the noise band was observed for L values between 2.5 and 5. Since the cube of L is inversely proportional to the magnetic field where the L shell crosses the magnetic equator, the frequency of the lower edge of the noise band f_{low} is proportional to the magnetic field B_0 or the gyrofrequency f_H at the peak of the line of force on which the noise is observed. This fact is illustrated in Figure 2 in which results from noise bands observed on several different days are combined. At high latitudes, i.e., $0.01 > B_0 > 0.003$, f_{low} varies approximately linearly with B_0 but shows no consistent pattern from day to day. At lower latitudes, i.e., $0.02 > B_0 > 0.01$, f_{low} is not only proportional to B_0 but the slope of the points on the (f_{low}, B_0) plots is about the same for all events. Moreover, for a given value of B_0 in the range $0.02 > B_0 > 0.01$, the points appear to cluster about two frequencies separated by 3.5 kc/s.

At very high latitudes, i.e. $B_0 < 0.002$, a noise band, which varies with the position of the satellite in a way similar to lower latitudes, is sometimes found, but the slope of the points on the (f_{low}, B_0) plot is very much steeper.

It is not possible at present to give any final explanation of these noise observations, but certain of their features are suggestive. The fact that it is the lower edge of the noise bands, rather than their central frequencies, which, for several events, has a constant relation to the geomagnetic field suggests that a cutoff mechanism may be involved. Such a cutoff could be due to propagation conditions which determine what frequencies are trapped on a given magnetic field line, or it may be associated with a cutoff in the spectrum of the energetic particles that radiate in the VLF band. At any rate, these noise bands seem to possess some well-defined features which repeat from event to event and hence should be of value in studying the structure of the exosphere or the generation of VLF noise.

Reference

Barrington, R. E., and J. S. Belrose, Preliminary results from the very low frequency receiver aboard Canada's Alouette satellite, *Nature, 198*, 651–656, 1963.

(Received September 18, 1963.)

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