Radiolocation of magnetospheric turbulence

A. M. Babichenko, A. V. Gurevich, A. N. Karashtin, and V. O. Rapoport
Scientific-Research Radiophysics Institute, 603600, Nizhnii Novgorod

(Submitted 19 December 1990)
Pis'ma Zh. Eksp. Teor. Fiz. **53**, No. 3, 139–143 (10 February 1991)

Preliminary results of a radiolocation study of the auroral magnetosphere in the short-wave band are reported. The spectral characteristics of the signal correspond to a scattering by ion acoustic turbulence in the region of longitudinal currents at heights on the order of 4000 km.

Research on the magnetosphere carried out with the help of satellites has shown that the plasma in the auroral region is highly turbulent over a broad range of heights, from 1000 to 13 000 km (Refs. 1 and 2). Satellites make it possible to determine all the plasma properties directly, but they draw only a static picture along the orbit of the satellite. We would also like to know about the dynamic behavior of the turbulence and its spatial distribution. Such information can be obtained by making use of the scattering of radio waves by plasma density inhomogeneities when the magnetosphere is sounded from the earth's surface. As we know, the ionospheric plasma is studied up to heights on the order of 600 km by an incoherent-scattering location method. Such measurements provide exceptionally rich information about the physical properties of the medium. This letter reports a first attempt to carry out a corresponding study of the magnetosphere.

Convenient facilities for sounding the magnetosphere are the existing short-wave facilities designed for studying nonlinear effects in the ionosphere,[1] in particular, the Sura heating station of the Scientific-Research Radiophysics Institute. The Sura station operates in the frequency band 4.5–9 MHz, which is a suitable band. It has a high effective radiated power of 150–300 MW. Its antenna system is capable of pointing the directional pattern in the north-south direction at angles up to 40° from the vertical. The geographic position of the Sura station (see the experimental geometry in Fig. 1) makes it possible to sound the auroral region at heights on the order of 3000–5000 km at the maximum (40°) northward inclination of the directional pattern. At present, the station is not capable of operating at full power in the location mode; the effective radiated power in the location mode cannot exceed 20–30 MW.

The first experiments on magnetospheric location were carried out on 21 February 1989 at 21–22 UT (near local midnight), at a time when the cutoff frequency of the ionosphere was no greater than 3 MHz. A frequency of 9.310 MHz (a wavelength $\lambda_0 \approx 32$ m) was used for the location. The effective radiated power was 30 MW. The receiving antenna had an area of 3×10^4 m^2. Since the scattered signal expected would not exceed the average noise level in the given frequency range, the location method described in Ref. 3 was used. This method involves the use of long coded pulses with a biphasal modulation. A processing of the received signal generates an estimate of the autocorrelation function of the scattering region with a fairly high time resolution and a correlation delay, which determines the spatial and spectral resolution of the loca-

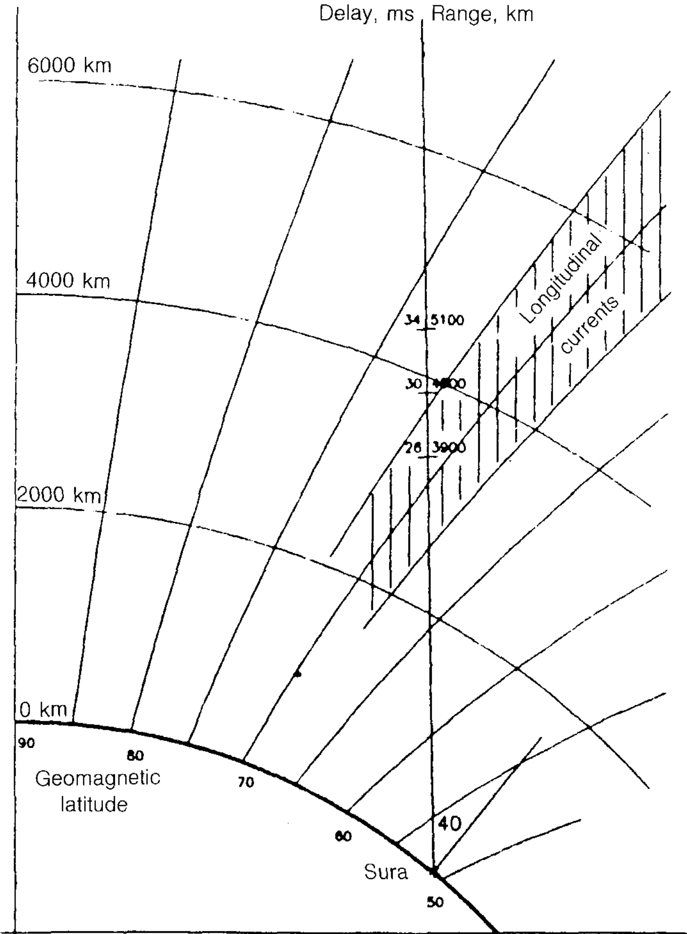

FIG. 1.

tion system. The spatial resolution and the frequency band surveyed are determined by the length of the elementary coding pulse. In these experiments, this pulse length was 500 μs; the corresponding spatial resolution was 75 km, and the corresponding frequency band was $\pm$ 1 kHz. The spectral resolution is determined by the code length; for the 8-bit code used in the experiments, this resolution was 125 Hz. The pulse repetition period was 70 μs; reception was carried out in the time-delay interval 16–56 ms (corresponding to ranges of 2400–8400 km).

Figure 2 shows spectra of the scattered signals from various ranges, averaged over 85 realizations, selected from a 15-min interval in which the interference from radio stations was at a minimum. The spectral intensity in Fig. 2 is given in arbitrary units. In addition, the noise level, found by the same method with the transmitter turned off, was eliminated. Unfortunately, it was not possible to obtain scattered-signal spectra at delay times shorter than 27.5 ms because of the very strong inclined-return sounding

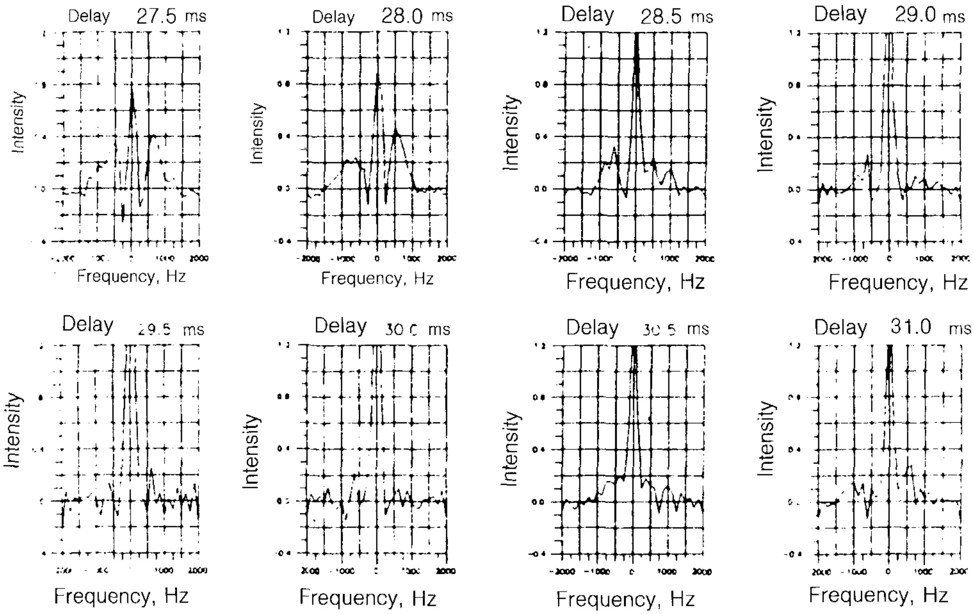

FIG. 2.

signals[2] which fell outside the directional pattern of the antenna and also because of the comparatively narrow dynamic range of the detection ($\sim$40 dB).

Analysis of the spectra of the scattered signals yields the following conclusions. (1) There is a strong scattered signal at zero frequency (with respect to the transmitter frequency) on all the time delays analyzed. This signal corresponds to an inclined-return sounding of the ionosphere outside the directional pattern of the location system. (2) On the first time delays, 27.5–28.5 ms, which correspond to ranges of 4125–4350 km, there are two broad side lobes in addition to the central lobe at the zero frequency. (3) The frequency shift of these side lobes is 500 Hz. This shift corresponds to the frequency of ion acoustic waves with a wavelength $\lambda = \lambda_0/2$ at heights on the order of 4000 km in the polar magnetosphere. (4) At the distances at which the side lobes are observed, the radar beam intersects a region of longitudinal currents (the auroral region; see the experimental geometry in Fig. 1). (5) These side lobes are not observed at long time delays. (6) Theoretical estimates show that the observed signal intensities are consistent with data obtained on satellites.[1,2]

One might therefore suggest that ion acoustic waves are excited in the auroral region of the polar magnetosphere. These waves can be studied by the method proposed here.

We are indebted to the Max Planck Institute of Aeronomy for the opportunity to use their computer facilities to analyze the results of these experiments.

[1)] The effort to evaluate the capabilities of radiolocation of the magnetosphere was undertaken by the present authors in collaboration with P. Stube (of the Max Planck Institute of Aeronomy, FRG) and Yu. M. Yampol'skiĭ (of the RI, Academy of Sciences of the Ukrainian SSR, Kharkov) in 1988. The heating station at Tromsö, Norway, and the UTR-2 radiotelescope were used.

[2)] The inclined-return sounding signals are radio waves on a sloping path which have been reflected from the ionosphere and backscattered by the earth's surface.

---

[1] F. S. Mozer *et al.*, J. Geophys. Res. **84**, 5875 (1979).

[2] L. P. Block *et al.*, Geophys. Res. Lett. **14**, 435 (1987).

[3] M. S. Lehtinen and I. Haggstrom, Radio Sci. **22**, 625 (1987).

Translated by D. Parsons