Generation of radiation at combination frequencies in the region of the auroral electric jet

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An experiment was performed aimed at recording radiation at combination frequencies when the ionosphere is acted upon, by high-power amplitude-modulated short-wave radio emission in the region of the auroral electric jet. It is found that the intensity of the radiation at the combination frequency depends on the distance between the auroral current jet from the center of the zone of the active action in the ionosphere, as well as on the strength of the current in the electric jet.

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Experimental and theoretical results on nonlinear section of modulated short-wave signals in the medium-latitude ionosphere are reported in[1,2], where the authors have considered two possible detection mechanisms connected with modulation of the ionosphere currents and of the pressure of the ionosphere plasma. To study and verify the proposed nonlinear-detection mechanism, a special experiment was performed in the auroral zone.

The radio transmitter operated at a frequency of 3 MHz amplitude-modulated by a 2.5-kHz tone. The average transmitter power was 110 kW at a modulation depth 60%. We used in the experiment a zenith-radiation antenna with a gain $G \approx 100$. The receiving point for the low-frequency radiation was 80 km to the east of the transmitter. To monitor the position of the auroral electric jet we used a three-component magnetic-variation station located 80 km to the north of the transmitter. The experiment was performed at night from the first to the fourth of April 1976.

Figure 1 shows by way of example the results of the measurements of the amplitude of the artificial radiation at 2.5 kHz. Registration of the low-frequency signal started at approximately 3:30 simultaneously with the develop-

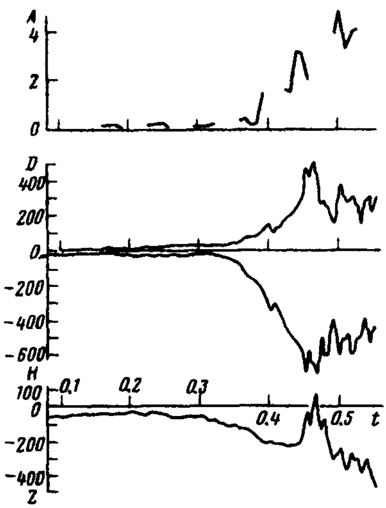

FIG. 1. Dependence of the low-frequency radiation, in relative units, on the variations of the magnetic field in γ ($\gamma = 10^{-5}$ Oe).

ment of the substorm in accordance with the data of the D, H, and Z components of the magnetic-variation station. There was practically no signal at quiescence.

Proceeding to the interpretation of the results, we consider the mechanisms whereby radiation is generated at combination frequencies. According to[2], the volume density of the nonlinear current $\mathbf{J}_\Omega$ at the difference frequency Ω is described by the expression

$$\mathbf{J}_\Omega = \hat{\sigma}^e(\Omega)\left[\frac{m}{e}\left(\frac{\partial \nu_e}{\partial T_e}\right)\mathbf{U}_0 + \frac{\nabla n_0}{n_0 e}\right]\Delta T_e \,, \tag{1}$$

where $\hat{\sigma}^e$ is the electronic part of the conductivity tensor of the ionosphere plasma, ν_e is the frequency of the collision between the electrons and the neutrals or the ions, T_e is the electron temperature, ΔT_e is the change of the electron temperature in the wave field, n_0 is the unperturbed electron density in the ionosphere, $\mathbf{U}_0$ is the electron velocity relative to the neutrals, and e and m are the charge and mass of the electrons. The current volume density $\mathbf{J}_0$ of the auroral electric jet is determined by the expression

$$\mathbf{J}_0 = \hat{\sigma}(0)\left\{\mathbf{E}_0 + \frac{1}{c}\,[\mathbf{v}_0 \times \mathbf{H}_0]\right\} \,, \tag{2}$$

where $\hat{\sigma}$ is the tensor of the ionosphere-plasma conductivity at a constant electric field, $\mathbf{E}_0$ and $\mathbf{H}_0$ are the constant electric and magnetic fields, $\mathbf{v}_0$ is the velocity of the neutrals, and c is the speed of light.

The main features of generation of low-frequency radiation in the region of the electric jet can be obtained from an analysis of expressions (1) and (2). Comparison of expression (1), which describes the nonlinear current due to modulation of the friction force, with expression (2) yields $\mathbf{J}_\Omega \sim \mathbf{J}_0$. The maximum of the linear current is located at a height close to 90 km, and that of the electric jet at about 120 km. Consequently the amplitude of the low-frequency signal is determined not only by the parameters of the current, but also by the height profile of the electron density. The second term of expression (2) is the nonlinear current due to the modulation of the pressure. In this case the non-

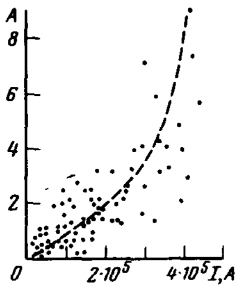

FIG. 2. Dependence of the amplitude of the low frequency radiation on the current strength in the auroral jet.

linear current is determined only by the profile of the electron density. The nonlinear-detection mechanisms considered here predict an increase of the amplitude of the low-frequency during the time of the substorms that are characterized by an increase of the current densities and the electron density in the auroral ionosphere. We note also that if the nonlinear current is due to modulation of the ionosphere currents, then there should exist a close connection between the amplitude of the low-frequency signal and the parameters of the electric jet.

Figures 2 and 3 show plots of the low-frequency radiation against the current strength in the auroral electric jet and on its position relative to the center of the action. The parameters of the current jet were calculated from land-based data on the magnetic variations. Thus, the experimental data confirm the theoretical predictions that the amplitude of the artificial low-frequency signal increases during the periods of the substorms, and the amplitude of this signal is monitored by the parameters of the auroral electric jet.

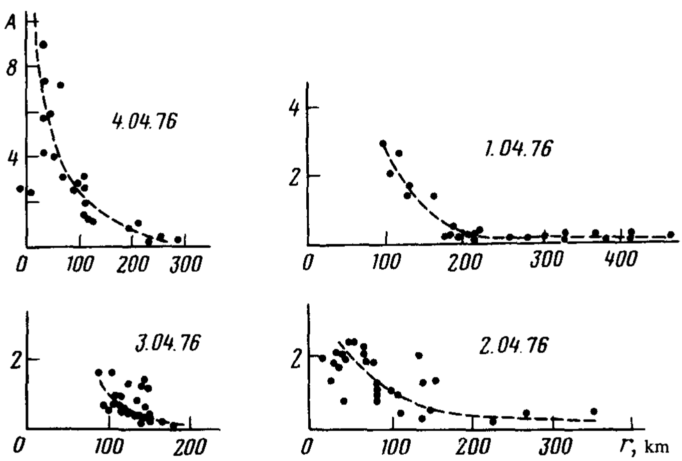

FIG. 3. Dependence of the amplitude of the low-frequency radiation on the position of the current jet.

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