NARROW-BANDED ELF EMISSIONS AND AURORAL DISTURBANCES

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Abstract. Narrow-banded emissions (f=130-260 Hz), registered on board the Aureol-3 satellite for several years, were received at the auroral zone station Apatity. Comparison with the data of the magnetometer located also in Apatity showed that the emissions were observed just before or at the beginning of a magnetic disturbance. The connection of the observed emissions with auroral arcs confirms the generation of these emissions by the electron beams. The properties of the considered narrow-banded ELF emissions can be used for the investigation of the electron acceleration region.

Introduction. The narrow-banded ELF emissions were observed at the altitudes of 10^3 -10^4 km on board ISIS-1,2, Viking, Aureol-3 satellites [1-4] at the frequencies below the local H^+ gyrofrequency. The emissions were detected in the region of 65 -75^o invariant latitude, mainly in the evening and premidnight hours. The wave electric field amplitudes were 3-10 mV/m and the magnetic field amplitudes 10-30$m\gamma$. The narrow-banded ELF emissions were registered in the region of the intensive auroral inverted V electron precipitation. Typical electron fluxes of such precipitation were bigger than $5*10^8$ el/cm^2 sr keV with energy 0.3-1 keV. Usually these emissions were observed simultaneously with VLF hiss, which was generated by auroral electron fluxes.

The indicated ELF emission characteristics make suppose that auroral electron beams responsible for the inverted V electron precipitation and for the discrete auroral forms are the most probable source of the free energy for the generation of the considered emissions. When the interaction of the upper ionosphere plasma with the auroral electron beam at the frequencies below proton gyrofrequency $\omega \langle \omega_{Bi}$ is considered the Cherenkov mechanism of the generation of Alfven polarization waves with the large angles of the wave normals is the most effective. The characteristics of the emissions generated under the instability of the auroral beam depend on both ionospheric plasma parameters and parameters of the beam.

If the condition $\left|\overline{k} * \Delta\overline{V}_e\right| \langle\langle \gamma_h$ is fulfilled, the instability is hydrodynamic one, and $\gamma_h \sim (n_b / n)^{1/3}$. In the opposite case, when $\left|\overline{k} * \Delta\overline{V}_e\right| \rangle\rangle \gamma_k$ this instability is kinetic one, and $\gamma_k \sim n_b / n$. Here $\overline{k}$ is a wave vector, $\Delta\overline{V}_e$ is the average deviation of the beam electron velocity determined by the distribution function, γ_h, γ_k are the growth rates of the hydrodynamic and kinetic instability; n_b, n are the beam and ionospheric plasma densities. Hence it follows that the auroral electron beams will generate emissions more effectively in the region of auroral electron acceleration where n has a minimal value. The aim of this paper is the investigation of the acceleration region with use of the narrow-banded ELF emission observations on board Aureol-3 satellite.

Characteristics of the narrow-banded ELF emissions registered on board Aureol-3. The registration of the electric and magnetic wave field components from satellite was carried out in Polar Geophysical Institute, Apatity (L=5). We examined the data obtained from Oct. 1981 till Febr. 1984. The narrow-banded ELF emissions had the following characteristics: the central frequency was in the interval of 150-220 Hz, the bandwidth was of a few tens of Hz, the emission duration was about 10-15 s. The emissions observed in the whole satellite altitude range (400-2000 km) during the autumn, winter and spring months, on the geomagnetic latitudes 60 -70^{o} .

The seasonal variation of narrow-banded ELF emissions occurrence. The dependence on season of the narrow-banded ELF emission occurrence in the evening and premidnight sector (18-24 MLT) was defined from the analysis of 250 crossings (Fig.1). The probability of the emission observation is calculated as a relation of number of crossings with emissions to the total number crossings for a considered month. It has been obtained that the probability of the emission observation in winter months is maximal (25%) and it decreases in autumn and spring seasons to 10%. In summer months the narrow-banded ELF emissions were not observed .

We explained the seasonal variation by the generation mechanism and by propagation processes of the narrow-banded ELF emissions. Indeed, the emissions generated in the auroral cavity propagate down to altitudes where

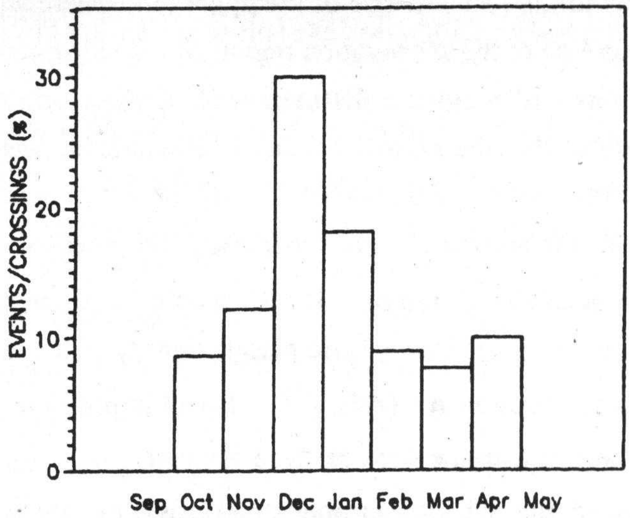

Fig.1. Dependence of the probability of the narrow-banded emission observation on a season.

emission frequencies are near the ion-ion hybrid resonance frequency ω_{ih} . The emissions will get full inner reflection in the region where $\omega_{\max} \sim \omega_{ih}$ because of sharp decrease of the transverse refraction coefficient at the lower altitudes. It means that the condition, under which the registration of the considered emissions is possible, is $\omega_{\max} \rangle \omega_{ih}$. The frequency ω_{ih} is determined by a heavy ion percentage. For the two-ion (H^+, O^+) plasma the frequency ω_{ih} is

$$\omega_{ih} = \frac{\omega_{Bi}}{R} \sqrt{\frac{1 + C(R-1)}{1 - C(R-1)/R}} ,$$

where $C = n_{O+} / n_e$, $R = m_{O+} / m_{H+}$; n_{O+}, n_e are the densities of O^+ ions and electrons; m_{O+}, m_{H+} are the ion masses of O^+ and H^+ . In winter, because of the decrease of the temperature T, the upper ionosphere altitude scale decreased as well as the percentage of the O^+ ions ($H_{ion} \sim T/m_{ion}$, where H_{ion} , m_{ion} are the altitude scale and the mass of a ion). It leads to the decrease of ω_{ih} and to the improvement of the conditions for the registration of the narrow-banded ELF emissions by low-altitude satellites. Moreover, one can expect the increase of the observation occurrence in connection with the possible lowering of acceleration region in winter season. In accordance with [5] the acceleration region is formed at the altitude where sharp increase of the Alfven velocity is observed (h< 10^4 km). The decrease of the upper ionosphere altitude scale has to lead to the decrease of the acceleration region altitude in winter months.

ELF events and magnetic disturbances. Comparison with the all-sky camera data showed that the narrow-banded ELF emissions were registered in the vicinity of auroral arcs (<200 km) [4]. During the magnetic disturbances the energy and flux of the auroral electrons increased and potential difference $\Delta\Phi_{\parallel}$ increased in the acceleration region. It was shown in [6] that such increase leads to the reduction of the ionospheric plasma density in the auroral cavity in accordance with the relation $\boldsymbol{n} \sim (\Delta\Phi_{\parallel})^{-1/2}$. It will impose the increase of the growth rate of the considered emissions since $\gamma \sim 1/\boldsymbol{n}$.

We selected the satellite auroral zone crossings situated near of the station Apatity meridian ($\Delta\lambda \langle 20^o$) to compare the observation of emissions with data of magnetometer located at this station (Fig.2a and 2b).

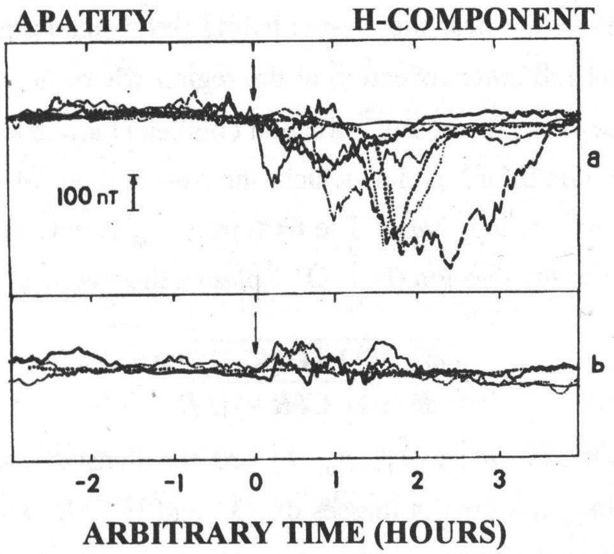

Fig.2a,b. Superposition of magnetograms when the receiving station Apatity (L=5) was under the westward, the eastward electrojet.

The arrows mark the time when narrow-banded ELF emissions were registered on board the satellite. It is seen that the emissions were observed just before or at the beginning of the local magnetic disturbance. Taking into account the fact of the increase of the potential difference at the beginning of the disturbance [7] we conclude that the considered events can be produced by such increase.

Conclusion. We have found that: a) the narrow- banded ELF emissions are observed in the vicinity of the auroral arcs; b) the emissions exhibit the dependence of their occurrence on season with maximal occurrence during winter months; c) the emissions are observed just before or at the beginning of the local magnetic disturbance.

The observed characteristics of the narrow-banded ELF emissions allow us to conclude that:

a) the emissions are the Cherenkov radiation of the auroral electron beam responsible for the discrete auroral forms;

b) the altitude of the acceleration region is decreased during the winter.

The observations confirmed the idea that the potential difference in the auroral cavity increased at the beginning of the magnetic disturbance.

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