VLF-NOISE IN THE DAYSIDE POLAR CUSP

Yu. V. Golikov, N. G. Kleimenova and V. A. Troitskaya

Abstract: VLF-noise measurements at several Antarctic ground stations (Mirny, Sleightrain and Vostok) are used as diagnostic of the parameters of the solar wind particles penetrating in the polar cusp region. The observed results revealed the higher level radiation zone in the dayside polar cusp region (geomagnetic latitude $\sim 79°$) when $Kp \leq 3$; two maxima of the daily intensity of VLF noise occur around 12 h and 18 h (local magnetic time). The coincidence in time of the VLF noise growth with soft electrons precipitation probability maxima indicates that VLF noise in the dayside polar cusp is generated by precipitating soft electrons.

Characteristic peculiarity of the dayside polar cusp is the presence of the electron beam with energy 100–200 eV and the number density $10^{-2}/\text{cm}^3$. This beam consists of the solar wind particles penetrating from the magnetosheath to low altitudes (Frank, 1971; Heikkila and Winningham, 1971). The electron precipitation in the dayside polar cusp causes generation of VLF hiss in the frequency range from several hundreds of herz to 1 MHz (James, 1973). The purpose of the work is to show that the VLF-noise measurements on the ground station may be used as diagnostic of the parameters of the solar wind particles penetrating in the polar cusp region.

For this purpose the simultaneous VLF noise measurements have been carried out at several Antarctic stations (Mirny, Sleightrain and Vostok). The results of these measurements revealed the higher level radiation zone in the dayside polar cusp region ($\lambda \sim 79°$) when geomagnetic activity is weak, ($Kp \leq 3$). There are two maxima of the daily intensity of VLF noise: the first one near 12 hours local magnetic time (MLT), the second—around 18 hours LMT (see Fig. 1). Fig. 1 also shows the statistic dependence of 0.7 keV electrons precipitation probability from the geomagnetic latitude and MLT (data OGO-4, Hoffman and Berko, 1971). The coincidence in time of the VLF noise growth with soft electrons precipitation probability maxima indicates the possibility of generation of VLF noise in the dayside polar cusp by precipitating electrons.

The spectral compositions simultaneously measured in the region of the higher level VLF noise ($\lambda = 79°$) and outside it (Mirny, $\lambda \simeq 77°$) are different. The high frequency noise is present in the higher level VLF noise zone ($f \geq 5$ kHz).

---

* Institute of Physics of the Earth, Academy of Sciences of the USSR, Moscow.

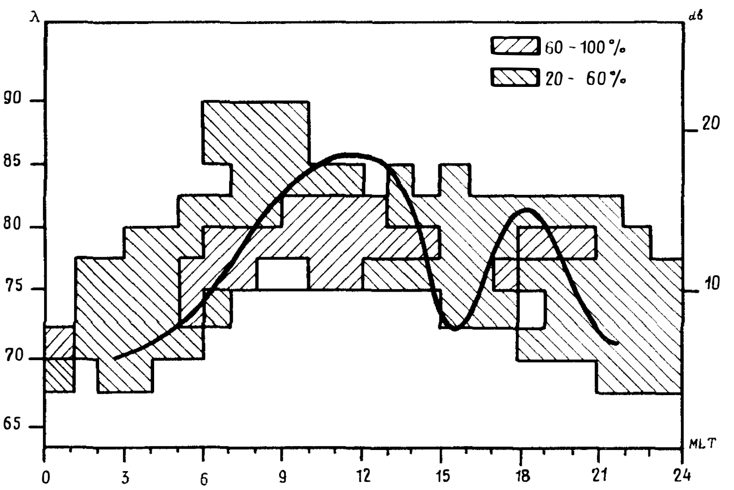

Fig. 1. *The change of VLF noise intensity (in dB) as function from the LMT (continuous line) at the 79° geomagnetic latitude (*Golikov *et al., 1975). The dependence of the 0.7 keV electrons precipitation probability from the geomagnetic latitude and MLT (data OGO-4,* Hoffman *and* Berko*, 1971).*

The frequency 5 kHz coincides with the minimum frequency of the low hybrid resonance (LHR) at the altitude near 1000 km.

We connect this VLF noise with the oscillations generated by the electron beam in the polar cusp region at the frequencies of LHR. Part of these oscillations may be transformed into the electromagnetic whistler-mode waves due to the density irregularity of the ionosphere. These oscillations then may be detected by ground stations.

The spectral distribution of intensity and VLF noise level is defined by nonlinear process which restricts the expotential growing waves generated by the beam. We interpret the results on the basis of nonlinear theory of waves generation of LHR by electrons beam in the magnetoactive plasma described in the papers (Golikov *et al.*, 1974, 1975).

The theory (Golikov *et al.*, 1974, 1975) is in a good agreement with the spectral range and with intensity of VLF noise registered on the satellites (Gurnett and Frank, 1972; Laaspere and Hoffman, 1971). The same theory make possible to interpret the above described new data which were measured at the ground station in Antarctica. According to the theory, quasistationarity spectral distribution of the energy LHR-wave $S(\omega)$ is defined by the excess $P= U_b/V_{fh}$ of the velocity of the beam U_b over the threshold for excitation of the instability $U_{th}=1{,}142_{Db}\sqrt{\omega_{Le}V_e}$, where V_e is collision of electrons with ions and neutrals frequency; Z_{De}, the Debai's of beam electrons; ω_{Le} is the Langmurs frequency of plasma electrons. The spectral distribution of the energy of LHR

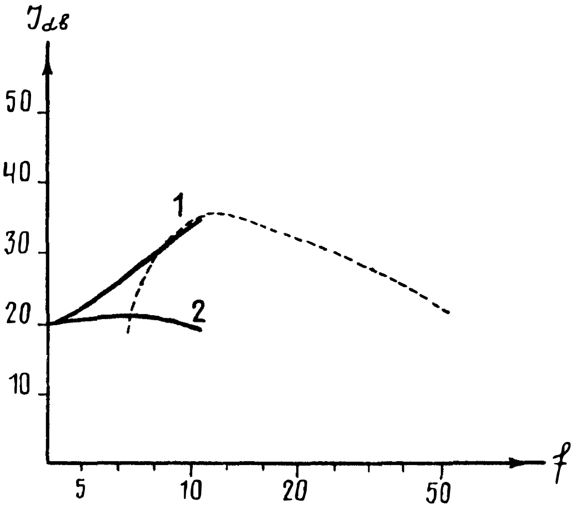

Fig. 2. The VLF noise spectral distribution measured at $\Phi=79°$ (curve 1) and at $\Phi=77°$ (curve 2). The dotted line denotes the distribution calculated from the formulae (1) when $f=1$ MHz (GOLIKOV *et al., 1975*).

noise according to the theory may be written in the form:

$$S(\omega)\propto\left(\frac{\omega_{\mathrm{Le}}}{\omega}\right)^2\left(\frac{\omega}{\omega_{\mathrm{Le}}}-1-P^2\frac{\omega}{\omega_{\mathrm{Le}}}\ln\frac{\omega}{\omega_{\mathrm{Le}}}\right)$$

$$\omega_1\leq\omega\leq\omega_{\mathrm{Le}} \tag{1}$$

$$\omega_1=\omega_{\mathrm{Le}}[1+P^2\ln\omega_{\mathrm{Le}}/\omega_1]^{-1}.$$

The calculated curve of the spectral distribution energy of LHR noise is shown by dotted line in Fig. 2. From Fig. 2 one may see that the suggested theory describes satisfactorily the LHR noise behavior near the lower boundary of the spectrum. In the future it is desirable to study the change in time of the VLF noise intensity predicted by the theory (GOLIKOV *et al.*, 1975) because the ratio Ω/Γ (Ω is frequency of oscillations and Γ, decrement of the damping of these oscillations) according to the theory equals $\sim 0{,}4U_b/V_{Te}$.

The measurements of the frequency corresponding to the VLF noise intensity maximum allows to define the value $P=U_b/U_{th}$ that is U_{th} and thus to find the number density U_b of precipitating electrons.

References

FRANK, L. A. (1971): Plasma in the earth's polar magnetosphere. J. Geophys. Res., **76**, 5202–5219.

GOLIKOV, Yu. V., V. V. PUSTOVALOV, V. P. SILIN and V. T. TICHONTCHUK (1974): Nelineinaya teoriya generacii shumov electronimi potokami v magnitoaktivnoi plasme. Kratkie soobsheniya po fizike. Fizitcheskii Institut, Akademii Nauk (FIAN), **3**, 14–19.

GOLIKOV, Yu. V., V. V. PUSTOVALOV, A. B. ROMANOV, V. P. SILIN, V. T. TICHONTCHUK and V. A. Troitskaya (1975): O prirode elektromagnitnogo izlutsheniya nizkoi tchastoti v polyarnoi shapke. Pisma v Zhurnal Eksperimental'noi i Teoretitcheskoi Fiziki (JETF), **22**(1), 3–7.

Gurnett, R. A. and L. A. Frank (1972): VLF hiss and related plasma observations in the polar magnetosphere. J. Geophys. Res., **77**, 172–190.

Heikkila, W. J. and J. D. Winningham (1971): Penetration of magnetosheath plasma to low altitude through the dayside magnetospheric cusps. J. Geophys. Res., **76**, 883–891.

Hoffman, R. A. and F. W. Berko (1971): Primary electron influx to dayside auroral oval. J. Geophys. Res., **76**, 2967–2976.

James, H. G. (1973): Whistler-mode hiss at low and medium frequency in the dayside cusps ionosphere. J. Geophys. Res., **78**, 4578–4586.

Laaspere, T. and R. A. Hoffman (1971): A comparison of VLF auroral hiss with precipitating low energy electrons using simultaneous data from two OGO4 experiments (Abstract). COSPAR, Seattle.