doi: 10.22564/rbgf.v13i1.1177

DYNAMICS OF INNER RADIATION BELT ELECTRONS AND THE SPORADIC SPACE RADIO EMISSION

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The simultaneous observations of the 0.3 - 2.0 *MeV* electron flux on board "Cosmos-1686" satellite and the sporadic radio emission on frequencies $f = 38$ *MHz* and $f = 325$ *MHz* at Kharkov University ground level station ($L = 2$), during and after the solar flare of November 20, 1986, were performed. The sudden increase in the counting rate of the radio emission sporadic bursts on November 25, 1986 and precipitation of subrelativistic electrons at the gap between the radiation belts were observed. It is supposed that a direct connection exists between the electron precipitation and the sporadic space radio emission on low latitudes.

Key words: Radiation belt; Sporadic emissions; Electron flux; Solar flare.

DINÂMICA DOS ELÉTRONS NOS CINTURÕES INTERNOS DE RADIAÇÃO ASSOCIADA À EMISSÃO ESPORÁDICA ESPACIAL EM RADIOFRE-QÜÊNCIA- *A observação simultânea do fluxo de elétrons de 0,3 a 2,0 MeV, a bordo do satélite "COSMOS-1686", e da emissão esporádica nas radiofreqüências f = 38 MHz e f = 325 MHz ,no laboratório da Universidade de Kharkov - Ucrânia, durante e após a erupção solar de 20 de novembro de 1986, foi efetuada. O aumento repentino da taxa de contagem da emissão esporádica espacial em radiofreqüência e a precipitação de elétrons sub-relativísticos em 25 de novembro de 1986, no intervalo dos cinturões de radiação, foram observados. Supõe-se que existe uma conexão direta entre a precipitação de elétrons e a emissão esporádica espacial de radiofreqüência em baixa latitudes.*

Palavras-chave: *Cinturão de radiação; Emissões esporádicas; Fluxo de elétrons; Erupção solar.*

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INTRODUCTION

The investigation of precipitation phenomena in the inner radiation belt region is of great scientific interest because it is connected with the problems of origin, accelleration and propagation of particles in the magnetosphere, interactions with ionosphere and atmosphere and has applied significance, also. During the last 20 years numerical measurements of high energy electrons (more than several 10 *MeV*) fluxes in the inner belt were performed (Gusev et al., 1983; Galper et al., 1983; Voronov et al., 1986; Nikolsky & Sinitcina, 1983). They found that large fluxes of such electrons exist in low altitudes in the Brazilian Magnetic Anomaly region (BMAr). When these electrons precipitate they can reach the deep layers of the atmosphere and produce significant ionization which can affect physical and chemical peculiarities of the atmosphere and climate parameters, also. Unfortunately, the phenomenology of precipitation in low L is not clear and is still contradictory. The mechanisms of particle dynamics at this region are extremely complicated and not very well known. The considerable fluxes of precipitating relativistic electrons were measured on "Cosmos-1686" orbits on altitudes 350-500 km in quiet magnetosphere (Pugacheva et al., 1993). Opposite the results of experiments on "Cosmos-1686" satellite, the precipitation of electrons with the energy up to 1 *MeV* was observed only at L=1.71±0.16 by satellite "OHZORA" in the quiet magnetosphere (Nagata et al., 1988).

At the top of magnetic field lines the high energy electrons of the inner radiation belt can produce the high frequency radio emission of synchrotron origin. As it was shown by Ginzburg (1987), the intensity of radio emission at frequency v of electron with the energy E in regular magnetic field H is:

$$S(v) = \sqrt{3}(e^3.H_\perp / mc^2).(v / v_c)\int_{v/v_c}^{\infty} K_{5/3}(\eta)d\eta \quad (1)$$

Here $v_c = (3eH_\perp 4\pi mc)(E / mc^2)^2$ and $K_{5/3}$ is a McDonald function.

The intensity of radio emission at frequency v of electron flux with the power law energy spectrum $I(E)dE = A.E^{-\gamma}dE$ is:

$$W(l,v) = A(l)\int_{E=mc^2}^{\infty} E^{-\gamma}S(v(E))dE =$$
$$A\sqrt{3}(e^3 / mc^2)\alpha(\gamma)\mathrm{H}^{(\gamma+1)/2}(3e / 2\pi m^3c^5v)^{(\gamma-1)/2} \quad (2)$$

Here $\alpha(\gamma)=((\gamma+7/3)/(\gamma+1)).\Gamma((3\gamma-1)/12).\Gamma((3\gamma+7)/12$ and l-is a length in the direction of sight. Here Γ is a Heiler function.

If the energetic electron flux at the top of the magnetic field is equal to A . $\int E^{-\gamma} dE = 10^3$ cm^{-2}c^{-1} and the space distribution of electrons is near the triangle with the top at L = 1.5 and width 0.3L (Dmitrenko et al., 1987), then the intensity of the synchrotron radiation along sight direction is equal to:

$$dI / dv = \int W(l,v)dl = 1.6 \bullet 10^{-19} / v^{(\gamma-1)/2},\ W/Hzm^2sr \quad (3)$$

For γ = 2.3 (Voronov et al., 1986), $dI/dv(v$ = 1 GHz) = *2.2 jansky/sr*, it is a very weak radiation and on the verge of measurability. But if these high energy electrons begin to precipitate into the low altitudes where the magnetic field value is ten times higher than at the top of the field line, the intensity of synchrotron radio emission will be greater and possibly can be measured.

The present paper is a result of the analysis of simultaneous observations of the sporadic radio emission at the frequencies of 38 and 325 MHz, registered by the ground level antenna and fluxes of the high energy electrons on board of "Cosmos-1686" satellite during the magnetic storm of November 25, 1986.

EXPERIMENTAL RESULTS

The "Cosmos-1686" spacecraft was launched in Sept. 27, 1985 on a circular orbit (500 km altitude, 51.6° inclination). Electron fluxes with kinetic energies 0.3 - 2.0 *MeV* were measured with two identical semiconductor spectrometers mounted outside the satellite at an angle of 90° of each other. Each spectrometer with a telescope of three semiconductor counters measured the energy of electrons at 4 differential channels: 0.3 - *0.6 MeV*, 0.6 - 0.9 *MeV*, 0.9 - 1.2 *MeV* and 1.2-2 *MeV*, at an aperture angle of ±20° (Mineev et al., 1981).

The radio bursts were detected with two radio-telescopes (RT) whose direction diagrams (DD) were azimuth-stabilized. The parameters of the first RT were: the operating frequency f = 38 MHz the DD with Δ0 = ±26°; the directive gain D ~ 80; the effective area S ~300m^2. The parameters of the second RT: f = 325 MHz; Δ0 = ±12°; D ~ 360; S ~ 20m^2 .

A solar flare of ball 1N with coordinates N24, E05 occurred in the interval of 08:54-09:59 UT, Nov. 20, 1986. The flare was accompanied by an X-rays burst. The flare-associated plasma flow reached the magnetosphere in November 23. The sudden commencement of the magnetic storm (SSC) at 09:24 UT in Nov. 24, 1986 coincided roughly with the change of magnitude and sign of the IMF vertical component (Bz). The main phase of the magnetic storm reached a minimum D_{st} = -105nT (Fig. 1). in Nov. 25, 1986. At that day, a sudden ionospheric disturbance (SID) which exhibited itself as a sudden enhancement of atmospherics (SEA) on middle latitudes at a frequency of 27 *kHz* was registered. At 14:30 UT, in Nov. 25, 1986, the instruments registered a sudden increase in the counting rate of irregular series of powerful short-time (0.2*s*) radio bursts with frequencies of 38 and 325 MHz (Fig. 1) at 50° N, 36.17°E (Kharkov, $L = 2$). The duration of each series was irregular and about 10-20 s. The counting rate of these series increased up to 150 per hour and remained at this level until interruption in the registration (01:00 UT, Nov. 26). The observations were continued after 12 UT, Nov. 26, but counting rate of burst was at the background level.

The electron fluxes with energy 0.3 - 2.0 *MeV* in the (BMAr) were measured on board the "Cosmos-1686" spacecraft before the onset of the magnetic storm, at the recovery phase and after its termination. It was shown (Abrosimov et al., 1991) that the inner belt electron fluxes with the 0.3 - 0.6 *MeV* energy increased comparatively with the undisturbed period but not as strongly as electron fluxes of 0.9 - 2.0 *MeV*, and the spectrum of electrons became more rigid. The maximum intensity shifted into the magnetosphere from $L = 1.8$ *to* $L \sim 1.65$. The electron fluxes with energy 0.3 - 0.6 *MeV* appeared within the gap between the inner and external radiation belts (in the region $L = 2.2$ - 3.4, at the altitude of 500 km) as a result of the storm. Unfortunately, just in Nov. 25, 1986, at the main phase of the magnetic storm, data from the satellite were not received because of telemetry upset.

DISCUSSION

Let us estimate an intensity of radio emission for individual bursts, assuming this emission is of synchrotron origin and produced by precipitating electrons. The calculation of $W(l,\nu)$ assumes that relativistic electrons precipitate sporadically from the top of magnetic line $L = 2$ to the altitudes of 100 - 300 km. The reasons of such assumption are the following.

First, the characteristic frequency of synchrotron radiation of electrons with the energy E at the magnetic field H is equal to:

$$\nu_c = 16H \cdot E^2, MHz \qquad (4)$$

Here, H - *gauss*, E - *MeV* . So radio emission at frequencies of 38 MHz and 325 MHz can be produced by electrons with the energy of about 2.7 and 9 *MeV* at the magnetic field $H\perp$=0.2 *gauss*, which is the horizontal component of the magnetic field value at the altitude of 200 km at the point of Kharkov ($L = 2$). Electrons with energies about several *MeV* exist on $L \sim 2$ but as a matter of fact with not very high energies as 9 *MeV*. The electrons irradiate synchrotron emission in a wide range of frequencies and the energy of electrons producing 325 MHz emission can be lesser.

Second, the Bauns-period of relativistic electrons and also the lifetime of precipitating electrons which can be observed over Kharkov is 0.2 s, because they loose their energy at the south hemisphere during one Bauns-period. The characteristic time of one radio emission burst is 0.17 s.

Third, if we take the energy dependence of the differential electron flux at the top of $L = 2$ in the form of power law with $\gamma = 2.0$ and $A = 5 \,.\, 10^{-10}$ *erg/cm³* and calculate intensity of synchrotron radio emission at the frequency $\nu = 38$ MHz, using Eqs. (2) and (3) and supposing $l = 200$ km, we will get

$$dI / d\nu = W(l,\nu) \cdot l = 1.46 \cdot 10^{-21}, W/Hz \cdot . m^2 \cdot sr \qquad (5)$$

The output at 325 MHz is 5.0 .10^{-22} $W/Hz.m^2.sr$. The above mentioned parameters of electron spectra at the top of $L = 2$ were used (Tverskoy, 1968) which describe maximal flux $10^7 1/cm^2s$ of electrons with the energy more than 0.5 *MeV*, taking into account an unstable state of hot plasma in magnetic field considerations.

The experimentally observed intensity of radio emission in individual bursts is:

$$P(\nu) = dI/d\nu \cdot \Omega = 1.46 \cdot 10^{-21}, W/m^2Hz, \qquad (6)$$

where Ω is the solid angle of the telescope (about 1sr).

Measured values of P (ν = 38 MHz) = 10^{-21} - 10^{-20}, W/m^2Hz and $P(\nu$ = 325 MHz) ~ 10^{-21}, W/m^2Hz agree with the calculated values of P by the order of value.

We do not discuss here the fine structure of radio emission effect, seen on Fig.1 (two peaked structure), because the radiation belt electron fluxes are so highly dynamical on the main phase of magnetic storm, that the two peaked structure could be explained by it.

CONCLUSION

So it seems that electron intensity at the top of the magnetic field line is sufficient to generate measured intensity of synchrotron origin radio emission. Unfortunately, we do not know if this strong precipitation really took place during this storm. But if this assumption will be confirmed by future experiments, it will supply us with a new method of observation of high energy particle precipitation using groundbased devices, that are less expensive and more convenient.

ACKNOWLEDGMENTS

This work was supported by SCTDE-SP, FAPESP-SP, CNPq and FAEP of Unicamp.

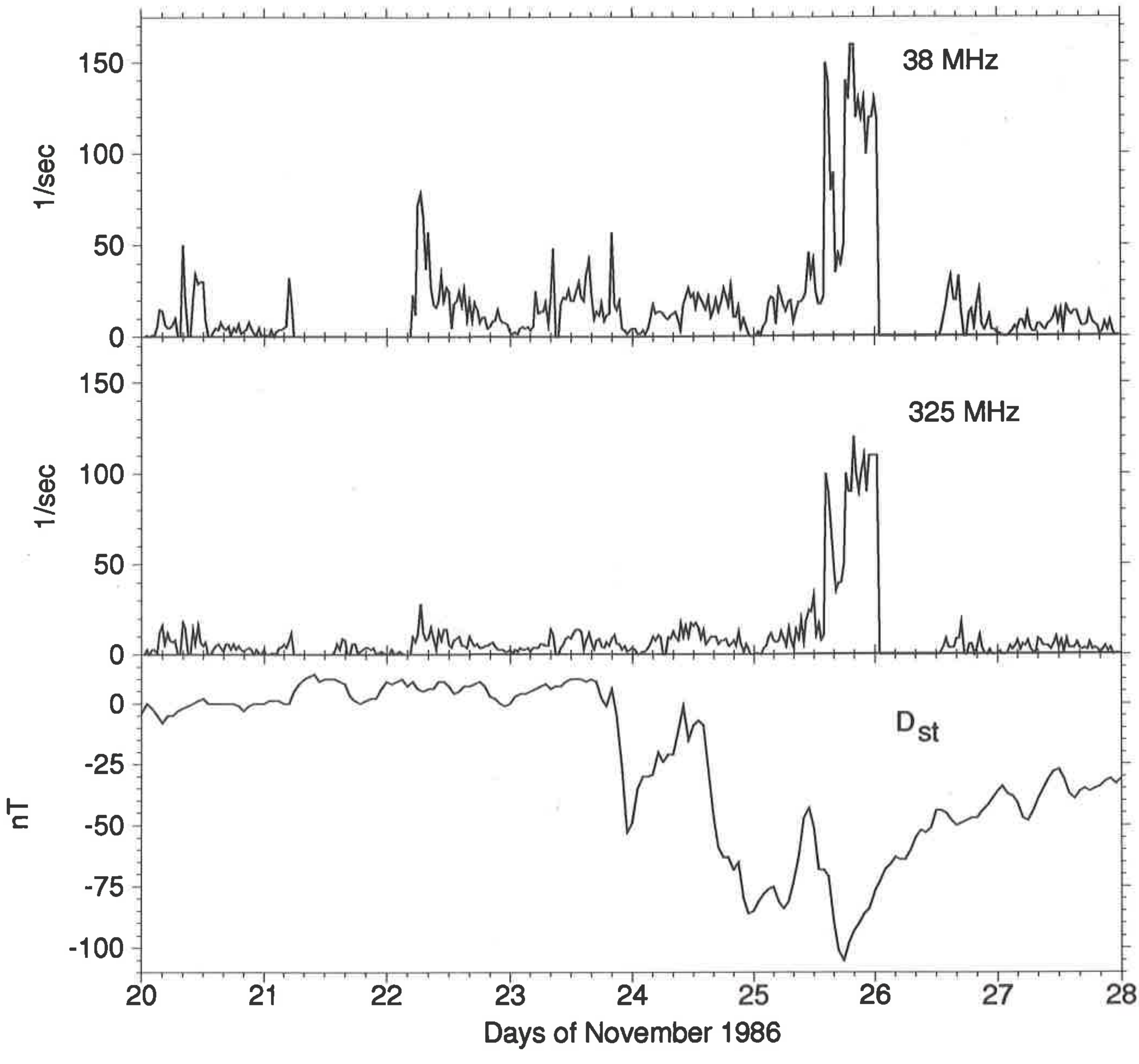

Figure 1 - Time dependence of D_{st} variation and counting rates of radio emission bursts in 38 MHz and 325 MHz during 20 - 27 Nov. 1986.

Figura 1 - *A dependência temporal da variação* D_{st} *e dà taxa de emissões em rádio freqüências de 38 MHz e 325 MHz entre 20 e 27 nov. 1986.*

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Submetido em: 16/07/93
Revisado pelo(s) autor(es) em: 27/04/94
Aceito em: 10/09/94