RESEARCH OF GEOSYNCHRONOUS SPACECRAFT CHARGING EFFECTS IN TERMS OF THE ONBOARD HOT PLASMA SPECTROMETER DATA

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Abstract

Russian geosynchronous GORIZONT and ELECTRO spacecrafts were equipped with electron and proton flux analyzers for hot magnetosphere plasma investigations. The measured energy range was from 0.1 to 12.4 keV. Abrupt variations of the electron and proton energy spectra were observed during the spacecraft charging. The variations enable to estimate the spacecraft electrostatic potential with respect to the environmental plasma. GORIZONT and ELECTRO charging cases were registered when spacecraft passed eclipse during vernal and autumnal equinoxes, as far as on the sunlit orbit segments. Good correlation of the spacecraft charging cases with 12.4 keV electron fluxes increase was observed. In terms of the spectrometer data, the value of spacecraft electrostatic potential is estimated to be of order of several kilovolts. Proton spectrometer data validity for spacecraft potential estimation is lower than one of electron spectrometer data. The reason for the feature is probably connected with background noise and secondary effects.

1. Introduction

Geosynchronous spacecraft charging up to negative potentials of order of ~ 0.1–10 keV causes distortions of energy spectra of electrons and positive ions (protons) registered by the onboard spacecraft spectrometers. The spacecraft negative potential decelerates electrons, and the protons are accelerated. Differential spacecraft charging complicates the situation. Angular distributions of the registered electrons and ions and secondary charged particles, which are formed near the spacecraft surface make influence on the peculiarities of the energy spectra distortions. Nevertheless, values of the arising potentials can be estimated in terms of analysis of the spectrometer indication variations, and the information about differential spacecraft charging can be obtained in some cases. Advantage of the spacecraft charging analysis method with the help of the onboard electron and proton spectrometers is the opportunity of direct research of the spacecraft potential dependence on parameters of environmental magnetosphere plasma. Special attention is given to this question in the report. The experimental data presented in the report were obtained during years 1992–1993 on the GORIZONT spacecraft and during years 1995–1997 on the ELECTRO spacecraft.

2. Orientation and characteristics of spectrometers

Two pairs of electron and proton spectrometers were mounted on the GORIZONT spacecraft. The apertures of every spectrometer pair were directed mutually perpendicularly: one pair – in the anti-Earth directions, and for another – to the South. One pair of spectrometers directed to the North was mounted on the ELECTRO spacecraft. Electrostatic analyzers with the switch of voltage on deflecting plates were used for measurement of electron and proton energy all spectrometers, and secondary electronic multipliers were used for registration of particles.

GORIZONT spacecraft spectrometers contained 32 energy channels in the range 0.1–12.4 keV, and ELECTRO spacecraft spectrometers had 6 energy channels in the range 0.2–11.6 keV.

3. Experimental data

Some results obtained on the GORIZONT spacecraft were published earlier [1, 2]. Here we present one typical case of the GORIZONT spacecraft electron spectrometer indication variations when the spacecraft passed the Earth shadow during a vernal equinox.

Time variations of the electron flux registered in separate spectrometer energy channels are shown in the top of fig. 1. The characteristic dip of the spectrometer indications in the region of 18:00–19:00 UT corresponds to the spacecraft pass through the Earth shadow, where the spacecraft charging occurs.

Electron energy spectra registered before to the entrance in the shadow (top curves) and after the entrance (bottom curves) are shown in the bottom part of fig. 1. Strong suppression of the low energy part of the electron spectrum by the spacecraft negative potential is seen distinctly.

The similar experimental data were obtained on the ELECTRO spacecraft. When analyzing these data, we have paid the large attention to revealing of the spacecraft charging dependence of the environmental magnetosphere plasma parameters.

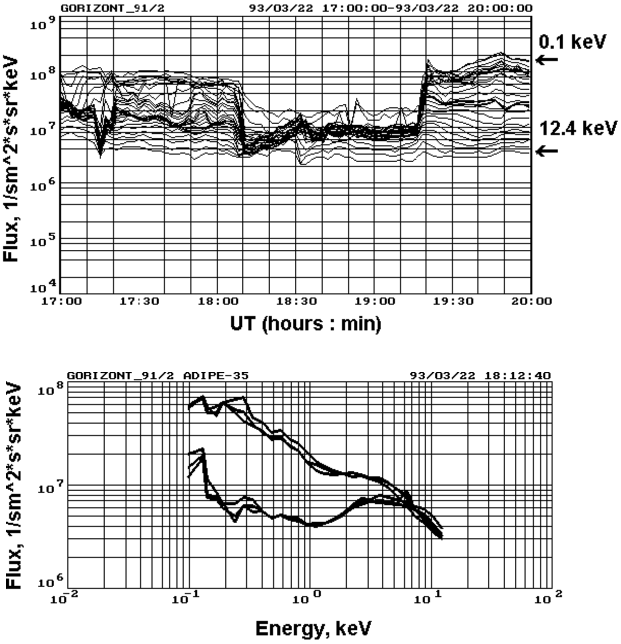

Fig. 1. Time variations of the electron flux registered by the GORIZONT spacecraft spectrometer during evening and night hours (top), and distortion of registered electron energy spectra arising due to the spacecraft charging

The spacecraft charging occurs mainly in night area of magnetosphere where spacecraft can enter plasma sheath. The charging reveals itself more distinctly in the case of complete absence of spacecraft illumination by the Sun in a shadow of the Earth, similarly to the case shown in fig. 1. Therefore, situations of this type in experimental ELECTRO spacecraft data were examined in the first turn.

The experimental ELECTRO spacecraft data can be divided into three groups.

The data corresponding the case when spacecrafts do not cross the plasma sheath on the night magnetosphere side refer to the 1st group. The situation is characteristic for low geomagnetic activity conditions ($K_p \sim 1$-2). The typical example of this group data is shown in fig. 2, where the dependence of fluxes registered in the separate ELECTRO spacecraft electron spectrometer energy channels is presented as function of local time during the vernal equinox (23.03.1995).

It is seen clearly, that there are no significant variations of the spectrometer channel indications in the evening and night hours in this case. When spacecraft passed through the Earth shadow (the shadow borders are shown by vertical dotted lines), no sharp variations of the spectrometer indications, which could point to the spacecraft charging were observed too. Thus, the spacecraft is not charged in the Earth shadow in this case.

Note that mean energy of the registered electron spectra E_{av} as function of time is shown in the bottom of fig. 2. The mean energy value is low (~2–2.5 keV), and varies slightly in this case. Vertical scale for E_{av} is shown on the right.

Typical example of experimental data of the 2nd group is shown in fig. 3, where the same dependences, as in fig. 2 are presented. Near 21:00 LT, we see here the sharp increase of flux values registered in the electron spectrometer channels. This increase corresponds to the entrance of spacecraft in the plasma sheath, but at the spacecraft pass through the Earth shadow near 0:00 LT there is no typical dip in the electron spectrometer indications similar to the case presented in fig. 1.

Note that the E_{av} value (bottom curve in fig. 3) grows at the ELECTRO spacecraft entrance in the plasma sheath, but does not exceed ~4 keV.

The data corresponding to the case when the spacecraft entrance in the plasma sheath between 20:00 LT and 22:00

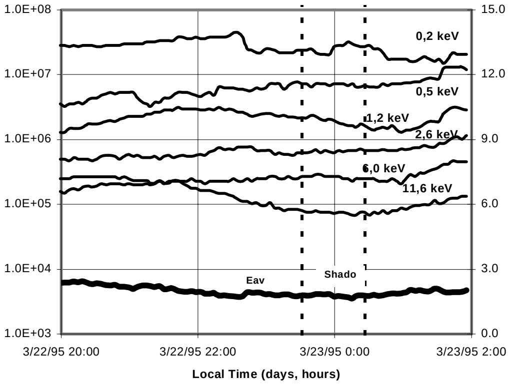

Fig. 2. The ELECTRO electron spectrometer data in the case of low geomagnetic activity

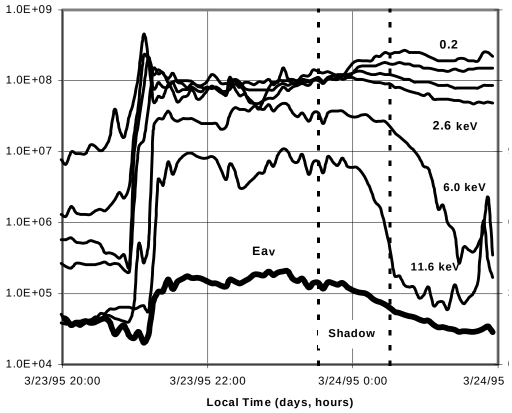

Fig. 3. The ELECTRO electron spectrometer data in the case of the spacecraft entry in the plasma sheath in the absence of charging

LT is registered distinctly, and characteristic dip of the electron spectrometer channel indications is observed when spacecraft crosses the Earth shadow refer to the 3^{rd} group (fig. 4). The mean energy E_{av} of the electron spectra reaches the value of 5-6 keV in this case. The situation is typical for conditions of the increased geomagnetic activity (K_p~4). Variations of the electron energy spectrum registered by spectrometer after the ELECTRO spacecraft entrance in the Earth shadow are shown in the bottom part of the fig. 4 in small windows. In the left window, the spectrum before the entrance in the shadow, and in the right one the spectrum after the entrance are shown.

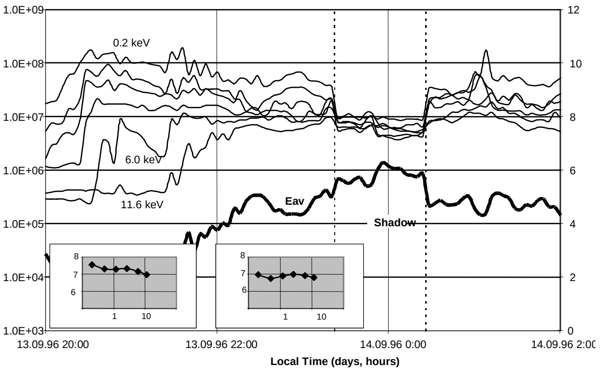

Fig. 4. The ELECTRO electron spectrometer data in the case of increased geomagnetic activity

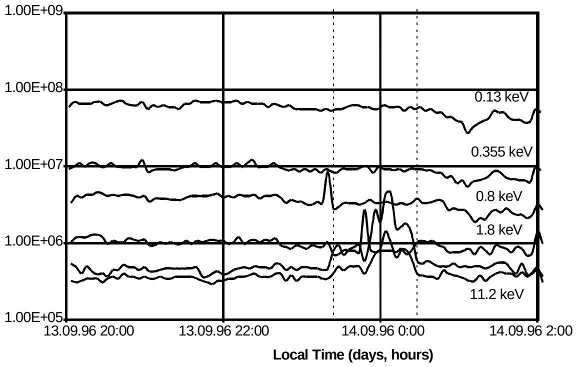

Fig. 5. The ELECTRO spacecraft proton spectrometer data

Unfortunately, the ELECTRO spacecraft charging is expressed less distinctly in the proton spectrometer indications in all cases. The same situation we observed earlier in experimental GORIZONT spacecraft data [1].

In fig. 5, the indications of proton spectrometer are given for the same period of time, as given in fig. 4. It is clearly seen on the fig. 5 that the proton spectrometer does not register increase of the proton flux in the time interval from 20:00 till 22:00 LT. And at the spacecraft pass through the Earth shadow, spectrometer indication variations have irregular behavior, and no reduction of the flux value was observed in energy channels 0.13 keV and 0.355 keV. These data are not explained by us up finally, and can be connected to background and secondary effects.

One more interesting case of the ELECTRO spacecraft charging in the conditions of the electron spectrum mean energy E_{av} strong variations is shown in fig. 6. In this figure, the area of the spectrometer indication characteristic dip formation on the sunlit orbit part in time interval between 20:00LT and 22:00 LT is shown by two vertical dashed lines. It is seen, that the dip of the spectrometer low energy channel indications is observed at sharp increase of the E_{av} value which is very similar to the dip found at the spacecraft crossing of the Earth shadow near 0:00 LT. Here, the area of the shadow, as well as in the previous figures, is shown by two vertical dashed lines.

In the bottom part of fig. 6, variations of the registered electron spectra are shown in small windows. Two spectra describing the degree of influence of the spacecraft negative potential are given in each window. It is clearly seen that the character of spectra variations is approximately identical in both cases of the spacecraft charging: on light and in the Earth shadow.

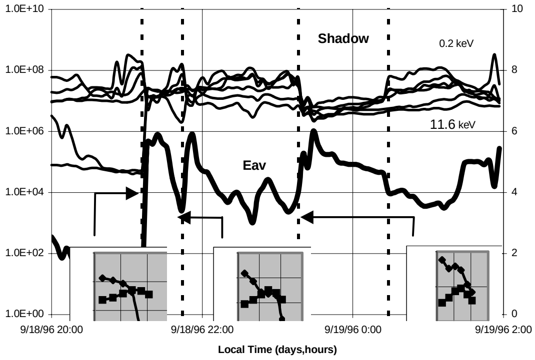

Fig. 6. ELECTRO spacecraft electron spectrometer indications in the case of electron spectrum mean energy E_{av} strong variations

4. Dependence of the spacecraft charging on the environmental magnetosphere plasma parameters

The experimental data above show that the spacecraft charging is observed in the case of rather high mean energy value E_{av} in electron spectra. This parameter can be used for estimation of the spacecraft charging opportunity alongside with traditionally used parameters of two-temperature Maxwell approximate function [1-3]. At the same time, it is possible to see the direct correlation between the spacecraft charging and the type of energy spectra of the incident electrons. In fig. 7, the case is shown when the electron spectrometer indications in the energy channel 11.6 keV vary significantly in time interval from 20:00 LT 12.09.1997 till 2:00 LT 13.09.1997. It is seen that the changes of the E_{av} value correlate well with variations of the electron flux in the 11.6 keV channel. It is seen also in fig. 7 that sharp increases of the electron fluxes in the 11.6 keV channel corresponds to the flux decreases in the low energy channels (0.2, 0.5, 1.2 and 2.6 keV) on the sunlit

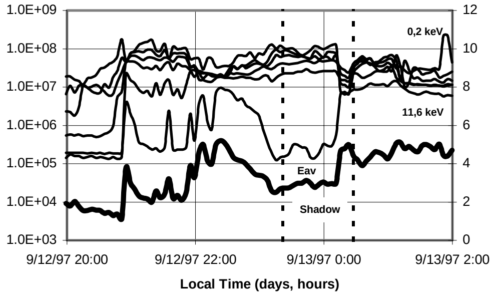

Fig. 7. The ELECTRO electron spectrometer data in the case of strong electron flux variations in the 11.6 keV energy channel

spacecraft orbit part in the period from 20:00 LT till 23:00 LT to 12.09.1997. These dips correspond to the spacecraft charging on the Solar light. Such cases we observed repeatedly.

We see further that the electron flux in the 11.6 keV channel has decreased considerably to the moment of the spacecraft entrance into the Earth shadow. Therefore, no dip of the spectrometer indications was observed at the entrance into the shadow. And after that, when the spacecraft was in the Earth shadow, the 11.6 keV electron flux started to grow quickly again. The result of the feature was the formation of a narrow dip before the spacecraft exit from the shadow.

In fig. 8, the electron energy spectra corresponding to the discussed above different measurements are shown.

The spectrum 1 concerns to the case shown in fig. 2, i.e. when the ELECTRO spacecraft entrance into the plasma sheath was not observed.

The spectra 2 and 3 correspond to different moments of time in a fig. 3, i.e. when the entrance into the plasma sheath is registered, but the spacecraft is not charged.

The spectra 4 and 5 correspond to cases shown in fig. 4 and fig. 7, when the ELECTRO spacecraft is charged. For clearness, spectra 3, 4 and 5 are extrapolated by dotted lines.

It is well seen after comparison of the spectra that the spacecraft charging occurs at presence of rather high fluxes of electrons with energies E ≥ 10 keV.

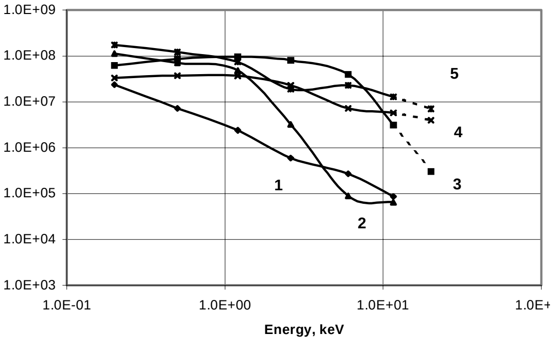

Fig. 8. Electron energy spectra for various conditions

Conclusion

The above results show that the measurements of the hot magnetosphere plasma characteristics with the help of geosynchronous spacecraft onboard spectrometers give, in addition, extensive information on spacecraft charging principles. The correlation between the spacecraft charging and the value of flux of magnetosphere plasma electron with energies higher 10 keV is observed in the measurement data distinctly. This correlation is well characterized by the mean electron spectrum energy E_{av} too. The results of magnetosphere plasma proton flux measurement are less suitable for the spacecraft charging analysis. Probably, it is connected to background and secondary effects and requires additional research.

References

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