A NEW METHOD FOR ON-BOARD MEASUREMENT OF HOT MAGNETOSPHERIC PLASMA AT GEOSTATIONARY ORBIT

V. V. Danilov, V.M. Dvoryashin, B.A. Elgin, S.S. Laptev

Research Laboratory Cosmophysics,
Krasnoyarsk State University, Svobodny 79, 660041, Krasnoyarsk, Russia

ABSTRACT

It is important to measure the near real time data of hot (T~10 keV) magnetospheric plasma at GEO. The electron energy spectrometers are widely used to measure these parameters. In present paper a new simple method based on "floating" potential difference measuring is presented. For GEO the electrons are in the range of energy where the "floating" potential is controlled by secondary electron-electron emission (SEE). The hot plasma temperature can be obtained from measured potential difference between two isolated plates with known factors of SEE. The cold (T~100eV) magnetospheric plasma which exists at GEO does not significally affect on the accuracy of measurements.

1. INTRODUCTION

Interaction of plasma environment with satellite at GEO produces the effect of high-voltage charging which led to damages of electronical systems. During magnetic substorms the fluxes of charged particles from the ambient plasma are increased that may produced differential charging of satellite surface and electrical discharges. So the space weather at GEO and near real time plasma parameters history are important for spacecraft anomalies prediction. The standard units of on-board plasma parameters measurements are complicated. So it is necessary to develop a new method for near real time monitor of ambient plasma at GEO. In present paper the method of double "floating" electrostatic probes is proposed by which it is possible by use of simple low cost on-board units to measure density and temperature of "hot" plasma.

2. DOUBLE "FLOATING"PROBE METHOD

2.1 "Floating" probe potential

According to classic theory of Langmuir electrostatic probe (Ref. 1) a "floating" potential of any body inserted into plasma is obtained from the balance of currents on its surface:

$$J_e + J_i = 0\,, \qquad (1)$$

where J_e and J_i are electron and ions current densities. For spherical geometry we have:

$$J_{e0}\exp\left(-\frac{e\varphi_f}{kT}\right) = J_{i0}\left(1+\frac{e\varphi_f}{kT}\right), \qquad (2)$$

where: $J_{e0,i0} = \frac{1}{4} env_{T_e,T_i}$ are undisturbed current densities of plasma electron and ions respectively, kT is plasma temperature, and φ_f is "floating" potential. Solving Eq.(2) we obtain:

$$\varphi_f = \frac{kT}{e}\ln\frac{\sqrt{\frac{M}{m}}}{1+\frac{e\varphi_f}{kT}} = 2.5\frac{kT}{e} \qquad (3)$$

2.2 Affect of secondary e-e emission

In the case of secondary electron-electron emission (SEE) with a factor of issue σ_{tot} , which is determined for Maxwellian energy distribution by:

$$\sigma_{tot} = \frac{1}{(kT)^2}\int_o^\infty \sigma(\varepsilon)\exp(-\varepsilon/kT)\cdot\varepsilon\cdot d\varepsilon$$

current balance Eq. (1) will be transformed to:

$$J_e + J_{SEE} + J_i = (1-\sigma_{tot})J_e + J_i = 0\,, \qquad (4)$$

since for spherical geometry

$$J_{e0}(1-\sigma_{tot})\exp\left(-\frac{e\varphi_f}{kT}\right) = J_{i0}\left(1+\frac{e\varphi_f}{kT}\right) \qquad (5)$$

This can be written:

$$\varphi_f = \frac{kT}{e}\ln\frac{\sqrt{\frac{M}{m}}(1-\sigma_{tot})}{\left(1+\frac{e\varphi_f}{kT}\right)} \qquad (6)$$

The solution of Eq. (6) $\varphi_f\,(\sigma_{tot})$ is shown in Fig.1.

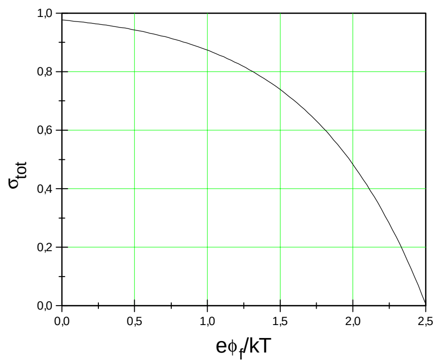

Fig.1 Dependence of φ_f *on* σ_{tot}

It is seen from Fig.1, that for two probes which are covered by materials with factors of SEE issue σ_{tot} : 0.8 and 0.6 the potential difference between them will be about *kT/2 e*.

As a result by measuring the potential difference $\Delta\varphi$ between any isolated probes we can get the plasma temperature:

$$kT = f(\sigma_1, \sigma_2) e \Delta\varphi \qquad (7)$$

2.3 Two component plasma

In the case when plasma is two component with temperatures T_1 and T_2 and $T_1 << T_2$, equation of current balance is given by:

$$(1-\sigma_{tot})J_e + (1-\sigma^c{}_{tot})J_e^c + J_i + J_i^c = 0, \qquad (8)$$

where subscript "*c*" corresponds to "cold" plasma component (T_1). Since the second item J_e^c is lesser then others due to the exponential dependence of electron current on potential, then

$$(1-\sigma_{tot})J_e + (1+\alpha)J_i \approx 0, \qquad (9)$$

where α is ratio of "cold" and "hot" plasma densities. For spherical geometry Eq. (9) can also be written:

$$\varphi_f \approx \frac{kT}{e} \ln \frac{\sqrt{\frac{M}{m}}(1-\sigma_{tot})}{(1+\frac{e\varphi_f}{kT})(1+\alpha)} \qquad (10)$$

Solving Eq.(10) it is possible to obtain the estimation of φ_f for a probe immersed into a two component plasma with $T_1 << T_2$.

3. DOUBLE "FLOATING" PROBE AT GEO

At geostationary orbit (GEO) there is a good approximation of plasma electron as a two-Maxwellian distribution. The results of on-board plasma parameters measurements are presented in Table 1.

Parameter	ATS-5	ATS-6	SCATHA
$n_1 (cm^{-3})$	0.58	0.75	0.78
$T_1 (keV)$	0.28	0.46	0.53
$n_2 (cm^{-3})$	0.22	0.27	0.31
$T_2 (keV)$	7.04	9.67	8.68

Table 1. Two-Maxwellian densities and temperatures of electron at GEO (Ref. 2)

From these data the temperature of "hot" plasma at GEO is about 10 *keV*, so inserting T_2 to Eq.(3) we obtain:

$$\varphi_f \approx -25kV \qquad (11)$$

As a result of SEE according to Eq. (6) the floating potential will decrease. If one probe is covered by titanium (σ_{tot} = 0.4) and second by niobium (σ_{tot} = 0.8) then the potential difference between them will be:

$$\Delta\varphi = 22kV - 13kV = 9kV \qquad (12)$$

(see Fig.1) at the temperature of ambient plasma *T*=10*keV*. This difference is proportional to T and will be change with ambient plasma temperature.

The disturbance of potential difference $\Delta\varphi$ as a result of presence a "cold" plasma at GEO (see Table 1.) is shown in Fig. 2.

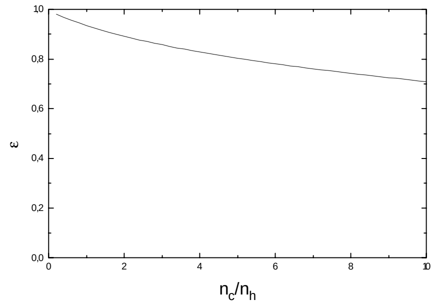

Fig.2 The disturbance of double probe potential difference by "cold" plasma

The disturbance of $\Delta\varphi$ by cold plasma (at α=3) is about 10% that quit acceptable of plasma temperature measurements in space.

4. SUMMARY

It was found that by use of double "floating" electrostatic probe method it is possible to develop a simple units of on-board "hot" plasma parameters measurement at GEO.

The sensors of electrostatic charge measurements on-board INTELSAT - VIII & VIIIA (Ref. 3) are very closed for realization of given method.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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