

VOLT-AMPERE CHARACTERISTICS OF A CYLINDRICAL PROBE IN THE IONOSPHERE PLASMA IRREGULARITIES REGIONS*

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Abstract

Cylindrical Langmuir probes are widely used for measurements of ionosphere plasma density and temperature. But a great deal of experimental data for such probe measurements fulfilled abroad “ICBulgaria-1300” satellite showed that Langmuir probe Volt-Ampere (V-A) characteristics with extraordinary forms were frequently observed. In this report it is shown that thanks to uneven distributions of plasma parameters inside irregularities, the Langmuir probe’s V-A characteristics whose execution time period happened to be close to those time intervals which were necessary for the satellite to pass through such irregularities, are subjected to some characteristic distortions. Also possible ways to originate these irregular structures will be discussed and it will be shown that sources for these structures can be situated in the magnetosphere or in the ionosphere.

Introduction:

The cylindrical Langmuir probes have been widely employed on rockets and satellites because of their manufacturing simplicity and possibility to measure electron density and temperature when magnetic field exists. The theory of moving cylindrical probe have been developed by taking into account the influence of the metal, used to cover the probe’s surface, the influence of the end effects, as well as the influence of the magnetic field over the results. The conclusion is that the material for probe’s manufacturing influences negligibly the accuracy of the measurements. The existence of the end effect and magnetic field, sometimes, under certain conditions, leads to situation that V-A characteristics of the cylindrical probe behave close to those of the spherical probe with the same diameter [1-9]. There is no complete theory about the behavior of the probe in a magnetic field, but the experimental

data show that, when the cylindrical probe radius is considerably bigger than the electron gyroradius, the magnetic field doesn't affect the measurements of the electron density and temperature. Up to now in scientific publications V-A characteristics of an unusual type were not shown. In this work unusual V-A characteristics will be considered, their appearance and the connection with the plasma irregularities will be discussed.

Measurements results:

Measurements are discussed that took place on board of the satellite "Intercosmos-Bulgaria-1300", launched on 07.08.1981. The data from cylindrical Langmuir probe, which collector is a metal cylinder, manufactured from stainless steel with a length of 11.5cm and diameter of 1mm, are used. The collector's sweep voltage period is 1 sec. The results from a three-electrode ion spherical probe with a floating potential on the outer cover are used to determine the density of the positive ions. Data from the electric field measurements, analyzer of low energy protons and electrons and three-component magnetometer are used.

On fig.1a the satellite orbit at 21.11.1981 in geographic coordinates and in invariant length-local time coordinates is shown. It could be seen that the satellite flew through subauroral and auroral regions, and entered the polar cap in the morning-night time as well. On fig.1b results of the electric and magnetic field measurements are presented. It could be noted that the Z component of the magnetic field has the largest value. On fig.2 some V-A characteristics of the cylindrical probe are shown. It is seen, that in the electron retardation region, where potentials applied to the probe are negative relative to the plasma, the characteristics have the usual form for such probe. In the electron saturation region (positive probe potentials relative the plasma) the characteristics have unusual form that the authors haven't seen in the literature yet. On fig.3 a values for ion density, measured by three-electrode ion probe, and electron currents with energy 1keV are shown. At that time, the satellite cross the auroral region, between the auroral and polar picks of ionization. On the plot of the ion density some large and comparatively small irregularities, with periods about 0.5-1 sec., could be seen.

Results discussions:

In the general case, the theory about the behavior of the probes when magnetic field exists, is not developed. However, in the plasma of the gaseous discharge with values of the magnetic field, such that the cyclotron radius of the electron is smaller than usual probe dimensions and smaller than the Debye radius, following the proposal of Bom, the ion part of the probe characteristic is used. The following considerations are taken into account. If the cyclotron radius of the electron is larger than the Debye radius, the particles movements in the coaxial sheath of charged particles surrounding the probe, can be considered as if the magnetic field is absent. It is supposed, that in the presence of magnetic field, the cyclotron radius should be considered rather than the path length of the free particles.

The works of Spivak and Reixrudel show that for a cylindrical probe, which radius is considerably smaller than the electron's cyclotron radius, the magnetic field doesn't affect the measurements of the electron temperature and density [4].

Smith mentions in Technical Manual of COSPAR that the magnetic field doesn't influence the measurements of the electron temperature, if the electron's cyclotron radius is larger than the probe radius and Debye radius [2]. In this case the magnitude of the probe electron current decreases. Dote and Amemiya have established that, if the axis of the cylindrical probe are parallel to the magnetic field lines, on the retarding region of the electrons the volt-ampere characteristic remains exponential when applied voltage values are close to the values of the plasma potential [3].

As was mentioned above, in the results description, we assume that in the electron retarding region the characteristic remains exponential for voltages, applied to the collector, corresponding to the plasma potential relatively the satellite airframe.

The distortion of the V-A characteristic begins in the regions where the voltages correspond to the electrons saturation. In this region begins the influence of the plasma irregularities, if the part of the period of the linear change of voltage, applied to the probe (and corresponding to the electron acceleration), is near the time interval during which the satellite pass through the irregularities. Note that, in the region of small density values, Debye radius

is near the cyclotron radius and the magnetic field begins to influence the form of the probe characteristic.

More over the satellite flows through a region of magnetic field lines, for which the main component of the magnetic field is almost vertical. So it is possible that the electric field, created by the probe, penetrates the sheath surrounding the probe, thus creating drift of the plasma in the crossed E,B field:

$$Vd \approx \frac{E}{B}$$

In this way the distortions of the V-A characteristics could be observed for small densities in the regions of inhomogeneous structures of the ionosphere and in the regions, where the main component of the magnetic field is almost vertical.

Here some remarks about the origin of the inhomogeneous plasma structures should be made. Their appearance in the aurora region should be connected, before all, with the precipitation of flows of electrons, whose energy exceeds the ionization potential of the ionosphere. Consequently, in ionization regions the plasma is electrically unstable. That can be the reason for the occurrence of the irregularities.

Conclusion:

Small electron density values $\approx 10^3 \text{cm}^3$ in the inhomogeneous plasma leads to comparable Debye radius and cyclotron one. That is the reason of the penetration of the probe electric field beyond the sheath surrounding the probe. At the same time the main component of the magnetic field is vertical. This generates a drift movement of the electrons and the ions in the plasma, so the electrons don't reach the probe surface. These effects explain the unusual form of the volt-ampere characteristic of the cylindrical probe.

References

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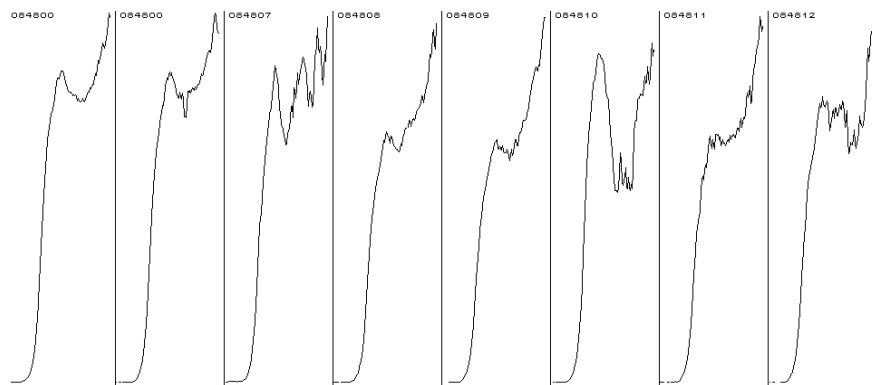


Fig.2

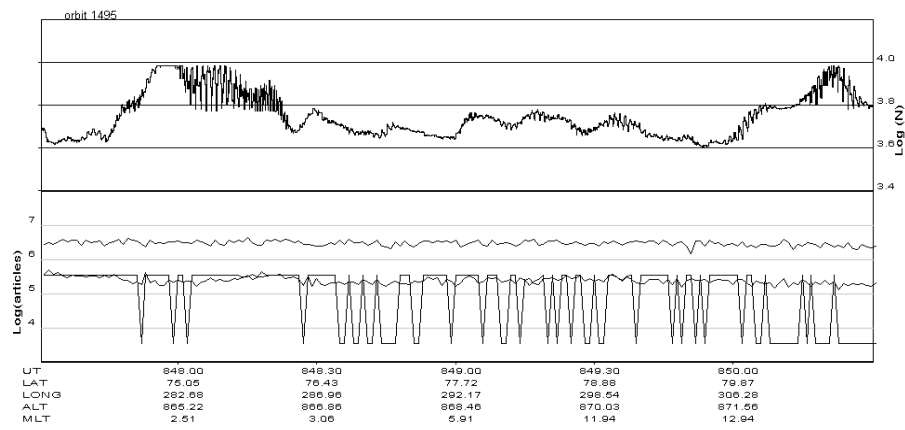


Fig.3