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Abstract

Full Text

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MEASUREMENT OF THE ELECTROSTATIC FIELD STRENGTH AT THE SURFACE OF GEOPHYSICAL ROCKETS

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An analysis of measurements of the electrostatic-field strength at the surface of geophysical rockets ([1]) showed that the inequality of the readings of two symmetrically placed sensors may be explained by three factors: the difference in the thicknesses of the volume-charge layers at each of them, the existence of an external electrostatic field, amplified at the surface of the rocket or satellite by some mechanism, and interference currents.

Fig. 1. Block diagram for measuring electrostatic-field strength. D_1, D_2—sensors, E—electrostatic generator, G—electromagnetic generator, K—collector, $I.B.$—measuring unit, U—amplifier, B—synchronous detector, P—cathode follower.

To determine the relative significance of these factors, measurements of the electrostatic-field strength were carried out with an electrostatic fluxmeter, constructed in accordance with the considerations set forth in ([2]), at the surface of a stabilized geophysical rocket of the USSR Academy of Sciences, launched on 15 November 1961.

The block diagram of the instrument is shown in Fig. 1. The sensors of the electrostatic fluxmeter were placed on the surface of the cylindrical part of the rocket symmetrically with respect to its axis at two diametrically opposite points. The

Fig. 2

Figure 2: Fig. 2

apparatus operated according to the same principle as that described in ([1]), but the measurement procedure was somewhat modified. First, the working plates of the electrostatic generator of the fluxmeter sensor were made of metal mesh. This made it possible to reduce both the modulation and the absolute magnitude of the fluxes of radiation and charged particles incident on the surface of the measuring plate ([2]). Second, the selection of the parameters of the input circuit and the use of special adjustment methods made it possible to tune the synchronous detector B to a minimum of interference voltage with an accuracy of about 3°, and thereby to increase the ratio of the signal voltage to the interference voltage ([3]). Third, the magnitude of the current produced by the flux of charged particles passing through the mesh plates of the electrostatic generator and reaching the collector K was measured. The latter made it possible to estimate the magnitude of the interference current and to obtain an idea of the effectiveness of the measures taken to combat it.

The measurement range of the apparatus used was ±6 V/cm. The measurement error associated with the effect of the interference current, the effect of the space charge created by the flux of charged particles penetrating through the grid plates of the fluxmeter sensor and simulated during rotation of the shielding plate, and the instrumental error did not exceed 0.4 V/cm. An unfavorable feature of the measurement scheme used was the dependence of the instrument readings on the location of the field source. This led to the fact that the absolute values of the electrostatic-field strength near the rocket surface were determined with an accuracy of the order of 20–25%.

The measurement results are presented in Fig. 2, curves 1 and 2. The electrostatic-field strength varies relatively little with altitude. Its value, measured by one sensor, varies within the limits 0.5–1 V/cm, and by the other, 1.8–2.5 V/cm. It should be noted that during the rocket flight sensor D_2 was illuminated by the Sun at an angle of 4°, while the other sensor was in shadow. The current to the collectors of the sensors along the entire trajectory did not exceed 10^{-9} A/cm^2.

The half-sums (see Fig. 2, 3) and half-differences (Fig. 2, 4) of the readings of both sensors were calculated. The results of the calculations are presented in Fig. 2.

Fig. 2

It can be seen that the electrostatic-field strength corresponding to the rocket' s own charge (curve 3) has, on average, a value of the order of 1.5 V/cm. Taking into account the measurement error and the inaccuracy in determining the true value of the field strength, this means that the average value of the electrostatic-field strength caused by its own charge in the experiment of November 15, 1961 was less than 2 V/cm, but greater than 1 V/cm. Thus, the rocket was negatively charged.

During the experiment the electron concentration at different altitudes was measured in parallel. From the data on the field strength and the electron concentration it is possible to calculate the potential of the rocket created by its own charge. It amounted to several volts. The value of the half-difference of the field strengths (curve 4) fluctuates within the limits 0.5–1 V/cm. The upper limit of the value cannot be explained by measurement error.

Let us consider, for example, the measurement of the electrostatic-field strength between 200 and 300 km. Without taking the error into account, the half-difference is equal to 1 V/cm. Taking into account the error of the method and the inaccuracy of measurement of the true value of the electrostatic-field strength at both sensors, 3.6 V/cm $\geq E_2 \geq$ 1.6 V/cm, 1.2 V/cm $\geq E_1 \geq$ 0.1 V/cm. This means that the half-difference must be less than 1.8 V/cm, but greater than 0.2 V/cm. Thus, at certain altitudes there exists a difference between the readings of the two sensors having a value at least of the order of tenths of a volt per centimeter. This difference in readings cannot be connected with the action of the Earth's magnetic field. It also cannot be connected with a difference in the thicknesses of the layers at the two instruments. Measurement of unipolar currents to the body by means of Langmuir probes, carried out on the same rocket, showed that the thickness of the layers should be practically the same at both sensors. Moreover, an increase in the layer thickness arising under the action of solar illumination should have led to a decrease in the noted difference.

Let us estimate the magnitude of the external field strength in the ionosphere, making certain assumptions about the nature of the phenomena near the surface of the rocket in the presence of an electric field. Let two flat conducting plates 1 and 2, connected to the body by a conductor, be placed on a negatively charged body 3 (Fig. 3). For definiteness, let us take the charge of the body to be negative. Before the appearance of the external field, both plates were under identical conditions, and the thickness of the layer at each of them was δ. Let a field of strength E_i arise in the medium, directed as indicated in Fig. 3. In this case the current of positively charged particles to plate 1 and of negatively charged particles to plate 2 will increase. The layer thickness at plate 1 will become $\delta_1 < \delta$, and at plate 2, $\delta_2 > \delta$. The field strength at plates 1 and 2 will change both owing to the appearance of an additional field E_1 and E_2 at the plates from the external field E_i, and owing to the change in the field from the body' s own charge due to the change in the layer thicknesses. If it is assumed that the magnitude of the drift velocity acquired by the particles in the external field constitutes a small part of the thermal velocity, then the deformation of the layers in these cases is small. Therefore, in weak fields $\delta_1 = \delta_2 = \delta$. The additional field created by the charges induced on plates 1 and 2 by the external field, obviously, likewise should not penetrate into the ionosphere beyond the layer of thickness δ. This assumption is valid if the potential difference due to the external field over a segment of length $2a$ is much smaller than the potential of the body due to its own charge. Since the surface of the body is equipotential, the potential drop U of the external field over the region occupied by the body must be concentrated in the regions δ_1 and δ_2. Then, if $a \gg \delta$, $U \approx 2aE$. The field strength E at the wall of the body, produced by the external field E_i, is equal to

$$E = E_\mathrm{i} \frac{a}{\delta}.$$

The amplification factor of the external-field strength a/δ at the walls of the body in our case is close to 100.

Thus, proceeding from the assumptions stated above, one may conclude that in the ionosphere during the experiment there existed an electric field with a strength of the order of 10^{-3} V/cm.

It seems to us that the results obtained may prove useful both for understanding the physics of the ionosphere and for interpreting the results of investigations carried out by direct methods. We hope that the continuation of similar investigations will make it possible to estimate the scale of the effect being studied and to clarify its cause.

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Note: Figure translations are in progress. See original paper for figures.