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Abstract

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GEOPHYSICS

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MEASUREMENTS OF THE ELECTROSTATIC FIELD STRENGTH NEAR THE SURFACE OF A ROCKET FLYING IN THE IONOSPHERE

(Presented by Academician A. L. Mints on 17 V 1962)

The flight of a rocket in the ionosphere is accompanied by a disturbance of the medium near its surface. One of the causes of this disturbance is the electrostatic charge of the rocket. For a number of problems (in particular, for ionospheric measurements carried out by means of rockets), the interaction of the rocket charge with the charged particles of the medium is of interest. Therefore, measuring the electrostatic field strength near the surface of a rocket flying in the ionosphere has both scientific and practical significance.

In 1957–1958, measurements were made of the electrostatic field strength near the surface of vertically launched geophysical rockets of the USSR Academy of Sciences. The experiments used the method of an electrostatic fluxmeter (^1). The measuring and shielding plates of the fluxmeter were flat disks with 6 uniformly arranged sector-shaped cutouts. The distance between the plates was chosen to be 3 mm. The electric motor used to rotate the shielding plate had a stabilized rotation speed of 9000 rpm. Two electrostatic fluxmeters were installed at diametrically opposite points of the cylindrical part of the rocket body. The voltage they generated, proportional to the electrostatic field strength, was fed to the measuring circuit, and the recorded values were transmitted to the Earth by means of a radiotelemetric system.

The use of two fluxmeters in principle makes it possible to separate the field strength produced by the body's own charge from the component of the external electrostatic field strength in the direction of the straight line connecting the fluxmeter installation points (^1).

Measurement of the electrostatic field strength near the surface of a rocket flying in the ionosphere is complicated by the presence of constant currents, modulated

Fig. 1

Figure 1: Fig. 1

by rotation of the shielding plate, flowing to the measuring plate. These currents are produced by free charged particles of the medium and by the photoelectric effect under the action of solar ultraviolet radiation.

A feature of the measuring circuit used was the simultaneous use of an automatic sensitivity switch and a synchronous detector. This made it possible to expand the range of measurements and, for the measured values of the electrostatic field strength, to distinguish whether changes in the output signal were caused by the measured (working) current produced by the electrostatic field near the rocket surface, or by modulated constant currents ("interference currents"). The synchronous detector attenuates the effect of interference currents on the output signals by approximately a factor of 5. At the same time, interference currents affect the automatic sensitivity switch in the same way as working currents. Therefore, if the input signal, measured from the readings at the output at the moment of sensitivity switching, is 5 times smaller than the signal at which switching should occur, the measured field-strength values are determined by interference currents rather than by working currents. The highest sensitivity of the circuit (before its switch-

···was such that a voltage of 0.1 V at the output corresponded to a field strength $E = 0.2$ V/cm. The sensitivity was to be switched in the absence of interference currents at $E = 6$ V/cm.

The first of the experiments described was carried out on 9 IX 1957 at 19 h 54 min after sunset, at a solar depression of -6°, which corresponds to an altitude of the earth' s shadow of approximately 30 km. During its flight in the ionosphere the rocket was not stabilized and could rotate. The second experiment was carried out on 21 II 1958 at 12 h 40 min. During this experiment the rocket was stabilized throughout the entire flight. Unfortunately, in this experiment no measurement results were obtained near the top of the trajectory. The third experiment was carried out on 27 VIII 1958 at 8 h 06 min. As in the preceding experiment, the rocket was stabilized during its flight in the ionosphere.

The most interesting result obtained at certain altitudes in all three experiments was the difference from one another in the electrostatic-field strengths measured simultaneously by two fluxmeters. This difference may be caused either by experimental errors associated with interference currents, or by an actual difference in the electrostatic-field strengths at the locations where the fluxmeters were installed. The latter means that, at the locations of the fluxmeters, the thicknesses of the layer of space charge surrounding the rocket are different.

Fig. 1

As laboratory tests of the apparatus showed, the maximum root-mean-square

Fig. 2 and Fig. 3: graphs of electric-field strength E versus altitude H.

Figure 2: Fig. 2 and Fig. 3: graphs of electric-field strength E versus altitude H.

instrumental error for the measured values $E < 3$ V/cm does not exceed 0.6 V/cm. Therefore, if differences in field strengths exceeding 1.2 V/cm are considered, instrumental errors may be disregarded.

Interference currents may be caused by: a) the motion of the rocket, causing inequality of the fluxes of charged particles onto the measuring plates of the two fluxmeters; b) photoemission from the measuring plates under the action of ultraviolet and X-ray radiation from the Sun; c) motions of the medium associated with ionospheric winds; d) the presence of an external electrostatic field. The same causes may create a difference in electrostatic-field strengths near the two fluxmeters, i.e., cause a difference in the "working" currents, according to the terminology adopted above.

Thus, the difference in electrostatic-field strengths measured simultaneously by the fluxmeters is due to a true difference in the field strengths at the locations of the fluxmeters only in the case where the "working" currents considerably exceed the "interference" currents.

Analysis of the operation of the sensitivity switch shows that, with the exception of several spikes in the results of the experiments of 21 II 1958 (altitudes 250–280 km on the ascending branch of the trajectory) and 27 VIII 1958 (altitudes 380–415 km, Fig. 3), the magnitude of the density of the interference currents did not exceed $5 \cdot 10^{-10}$ A $\cdot$ cm^{-2}, and the greater part of the measured values is associated with the true values of the electrostatic-field strength at the surface of the rocket flying in the ionosphere.

Figs. 1 and 2 present the results of measurements near the tops of the trajectories, obtained respectively on 9 IX 1957 and 27 VIII 1958. In all the figures the following notation is used: 1, 2 are the results of measurements by one fluxmeter during the ascent and descent of the rocket, respectively; 3, 4 are the same for another fluxmeter. All effects associated with the motion of the rocket are completely absent at the top of the trajectory and are small near it. Therefore the difference in the field-strength values measured by the fluxmeters, shown in Figs. 1 and 2, cannot be explained by effects associated with the motion of the rocket.

Fig. 3 gives the results obtained in the experiment of 27 VIII 1958. As is seen from the figure, the difference between the field-strength values measured during flight changes in magnitude and even in sign, although the position of the fluxmeters relative to the Sun did not change throughout the entire flight. Consequently, the indicated differences are not produced by electron photoemission. Thus, without invoking effects associated with the presence of

Fig. 2 **Fig. 3**

an external electrostatic field, it is impossible to explain the results obtained.

Consideration of the experimental data presented in Figs. 1 and 3 shows that: 1) over the greater part of the trajectory the electrostatic-field strength at the surface of a rocket flying in the ionosphere varies within the limits 0.2–3 V/cm and corresponds to a negative charge of the rocket; 2) there are sections in which the rocket has a positive charge.

The magnitude of the rocket' s charge density, calculated on the basis of the obtained values of the electrostatic-field strength under the assumption that

the rocket is a homogeneous conducting cylinder, lies within the range $5 \cdot 10^{-5} \div 10^{-3}$ CGSE $\cdot$ cm^{-2}.

Analysis of the results leads to the conclusion that in the ionosphere, in a number of cases, an external electrostatic field has been registered that is not associated with the appearance of the rocket in the ionosphere. Estimating the magnitude of the strength of this external field must be carried out with allowance for the specific character of the phenomena occurring near a body located in a plasma, and should be the subject of special consideration. In measurements of field strength by the electrostatic fluxmeter method it is advisable to use the procedure proposed in ([2]), which to a considerable extent eliminates the influence of interference currents, with which part of the results presented above is associated.

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