# Reports of the Academy of Sciences of the USSR

K. I. Gringauz and V. A. Rudakov

1960

SovietRxiv

**Abstract**

**Full Text**

## Reports of the Academy of Sciences of the USSR

1960, Volume 132, No. 6

### GEOPHYSICS

**K. I. Gringauz and V. A. Rudakov**

# MEASUREMENT OF ELECTRON CONCENTRATION IN THE IONOSPHERE FROM THE ROTATION OF THE PLANE OF POLARIZATION OF RADIO WAVES EMITTED FROM ROCKETS

*(Presented by Academician A. N. Shchukin on 14 March 1960)*

The purpose of the present note is to describe one of the methods for measuring electron concentration in the ionosphere, used in launches of geophysical rockets of the Academy of Sciences of the USSR to altitudes of 450 km and higher, and to present the results obtained by this method during the launch of 27 August 1958. The method is based on observations of the Faraday effect; the measurements are carried out by observing on the Earth the rotation of the plane of polarization of radio waves emitted from vertically launched rockets stabilized with respect to three possible axes of rotation.

From the formulas of the theory of radio-wave propagation in the ionosphere, taking into account the presence of the Earth' s magnetic field ([1]), it is not difficult to obtain that, for sufficiently high frequencies (at which absorption of radio waves may be neglected and the refractive indices for the right- and left-rotating components may be considered close to unity),

$$\theta = \frac{e^3}{2\pi c^2 m^2} \frac{1}{f^2} \int_{L_1}^{L_2} H_L N \, dl. \tag{1}$$

Here $\theta$ is the angle of rotation of the plane of polarization when radio waves pass along a ray over the distance $L_2 - L_1$, for an arbitrary direction of radio-wave propagation relative to the magnetic field; $e$ and $m$ are the charge and mass of the electron; $H_L$ is the component of the magnetic field along the direction of propagation; $N$ is the electron concentration. All quantities in (1) and below are in the Gaussian system of units.

Fig. 1

Figure 1: Fig. 1

It follows from (1) that if $\theta = \pi$, then, regarding the value $H_L$ as known and unchanging along the path $L_2 - L_1$, the mean electron concentration on the portion of the path under consideration may be written as

$$N_{\text{cp}} = \frac{2\pi^2 c^2 m^2}{e^3} \frac{f^2}{L_2 - L_1} \frac{1}{H_L}. \tag{2}$$

With the aid of formula (2), the height distribution of electron concentration in the ionosphere can be determined in a simple way during vertical launches of rockets fully stabilized in free flight. For this purpose it is sufficient, on the Earth near the rocket launch site, to receive on an antenna with linear polarization radio waves of sufficiently high frequency emitted from a vertically launched rocket by means of a linearly polarized antenna, and to record the amplitudes of the received signals. Since the coordinates of the rocket are known for every instant of flight, then, knowing the time during which the plane of polarization of the received signals has rotated by $\pi$ (from one amplitude minimum to the adjacent one), one can determine $L_2 - L_1$ and, knowing $H_L$, find $N_{\text{cp}}$ on this portion of the rocket trajectory.

If the rocket is not stabilized during flight, then measurements of the rotation of the plane of polarization of radio waves of a single frequency cannot be used to measure the electron concentration; in this case, in order to separate the rotation of the plane of polarization of the radio waves produced by the ionosphere from the rotation produced by the rotation of the transmitting antennas, reception of radio waves of at least two different frequencies and processing of the results are required, which is quite difficult.

Fig. 1. Portion of the plot of signal levels with frequencies $f$ = 24 MHz (1), 48 MHz (2), and 144 MHz (3), received during the flight of the rocket on 27 August 1958 (the curve for the 24 MHz signal is shown incompletely)

For vertical launches of rockets of the USSR Academy of Sciences stabilized with respect to three possible axes of rotation in 1958, radio-transmitting devices were installed on them, emitting coherent linearly polarized radio waves with frequencies of 24, 48, and 144 MHz ([2]). Reception of these radio waves was carried out near the rocket launch site by means of horizontal antennas with two mutually perpendicular linear polarizations; the signals received by the antenna of each polarization were fed to the input of a separate receiving device. The voltages at the input of each receiving device were recorded.

During the rocket flights, rotations of the planes of polarization of all the received radio waves were observed; maximum signal values in antennas with one

Fig. 2

Figure 2: Fig. 2

polarization corresponded to minimum (zero) signals in antennas with the perpendicular polarization. Figure 1 shows changes in the levels of the received signals on one of the trajectory segments. In the plots the dependence $\theta \equiv \frac{1}{f^2}$ (in agreement with (1)) is clearly visible, leaving no doubt that the observed effect is due to the rotation of the plane of polarization of the radio waves in the ionosphere.

Fig. 2. Dependence $N_{\mathrm{av}}(H)$, obtained on 27 August 1958. The lengths of the vertical segments correspond to the measurement intervals in altitude. The solid segments were constructed from practically coincident data from two receiving points, the dashed ones from the data of a third receiving point. The point shows coincidence of the values for all three points. The curve obtained from simultaneous measurements of the dispersion of radio waves with frequencies 48 and 144 MHz ($^2$) is given for comparison.

leaving no doubt that the recorded oscillations are caused by the Faraday effect.

From the data of the vertical launches of the indicated rockets, determinations were made of the mean electron concentrations over the altitude intervals traversed by the rockets, corresponding to a rotation of the plane of polarization of the radio waves through an angle $\theta = \pi$. For this purpose formula (2) was used, into which the value of the vertical component of the geomagnetic field $H_L$ was substituted in accordance with the available data on the magnitudes of the magnetic-field strength and magnetic inclination in the region of the rocket launch.

Figure 2 shows the height distribution of the electron concentration in the ionosphere, $N_{\mathrm{av}}(H)$, obtained by the indicated method from the launch data of the USSR Academy of Sciences rocket carried out on 27 VIII 1958 at middle latitudes of the European part of the USSR. The launch began at 8 hr 06 min. To construct Fig. 2, the results of recording signal levels at a frequency of 48 MHz were used.

A comparison of the height distribution of electron concentration obtained during the launch of the USSR Academy of Sciences rocket on 21 II 1958 [2] with the distribution obtained on 27 VIII 1958 shows a noticeable difference between them, consisting in the fact that in the second case the decrease with height of the electron concentration above the maximum of the $F$ layer was substantially slower.

Received9 III 1960

## References

1. A. N. Shchukin, *Physical Foundations of the Propagation of Radio Waves in the Ionosphere*, Moscow, 1940.

2. K. I. Gringauz, *DAN*, **120**, No. 6, 1934 (1958).

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