M. A. Kolosov and N. A. Savich. Study of the Space Plasma by the Dispersion Interferometer Method.

1. The dispersion method is highly effective for studying the space plasma (the ionospheres of the Earth and the planets and the interplanetary and circumsolar media). This method is based on the frequency-dependence of the phase velocity of propagation of radio waves. In performing such experiments, the transmitter of the space station emits several coherent signals, while an Earth-based complex of apparatus receives the signals, isolates them from the noise, and measures the needed phase relations among them. As the general theory implies,[1,2] multifrequency dispersion interferometers permit one in the first-order approximation to measure the absolute values and variations of the integral electron concentration along the trajectory of the ray, given an appropriate choice of the number and frequency ratings of the used signals. Under certain conditions, these measurements permit one to get information on the radial distribution of electron concentration in the ionospheres of planets and circumsolar space, and to study the mean characteristics and inhomogeneous structure of the interplanetary medium, the dispersion errors of the trajectory measurements, etc. More complex systems (dispersion interferometers having coherent and incoherent response) open up the possibility of studying non-steady-state processes in the cosmic plasma, as well as some other physical effects.

In order to solve this type of problems, a complex of rocket- and Earth-based dispersion interferometer apparatus has been developed and built in the Institute of Radio Engineering and Electronics of the Academy of Sciences of the USSR,[3] which operates in the ranges of decimeter ($\lambda_1 \approx 32$ cm) and centimeter ($\lambda_2 \approx 8$ cm) waves. The latter makes it possible to measure in a two-frequency system the variations of the integral electron concentration (and in a four-frequency system, the absolute values of it) along the space station-Earth course.

2. A two-frequency radio probe of the daytime ionosphere of Mars was performed for the first time by using the transmitter of the dispersion interferometer of the station "Mars-2", which was directed into a satellite orbit about the planet on Dec. 18, 1972.[4] Measurements of the reduced Doppler frequency were started ~ 25 minutes before occultation of the station by the planet's disk. The root-mean-square error of the measurements was determined from a region of the record not yet affected by the ionosphere of Mars, and it proved to be 0.017 Hz. The electron-concentration distribution N(h) in the ionosphere of Mars was calculated from the results of the measurements by using the known methodology over the altitude range $115 \leq h \leq 350$ km above the surface of the planet (Fig. 1). The calculated error of determination of N was $\sim 10^3$ cm^{-3}. We can consider the profile N(h) corresponding to this value to be reliable to an altitude of ~ 330 km. The concentration of electrons in the main peak that lies at 140 km altitude is 1.5×10^5 cm^{-3}. For comparison, Fig. 1 shows the distributions N(h) obtained from the results of simultaneous one-frequency radio probing[5] (the curve marked with circles) and from the data of the station "Mariner-9"[6] (dotted curve).

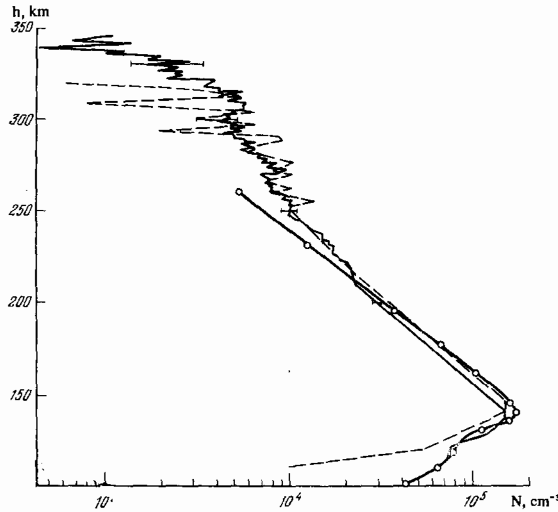

FIG. 1.

The higher accuracy of the applied method of study, as compared with the single-frequency method, made it possible to discover a break in the profile N(h) at a height of ~ 210 km. The altitude scale in the interval $150 \leq h \leq 200$ km is 36 km, while it is 57 km for $210 \leq h \leq 300$ km. These changes in the altitude gradient of the profile N(h) makes it possible to decide on the physical processes in the ionosphere of Mars and to refine the theory of its formation.

3. The transmitter apparatus of the dispersion interferometer on the satellite "Lunar-19" made it possible for the first time to perform a repeated radio probing of circumlunar space in order to detect and determine the fundamental physical parameters of the circumlunar plasma.[7] From the 15 courses of measurements performed in May—June, 1972, six were chosen for further treatment for which the masking effect of the Earth's ionosphere was minimal. During the three courses of May 8, 1972, the surface of the Moon at the point of contact of the ray at occlusion was not illuminated by the Sun, and the measured values of the reduced phase difference $\Delta\psi(t)$ lie near the zero line during the 40-second intervals before the instant of optical occlusion of the satellite behind the Moon. In the courses of June 11,

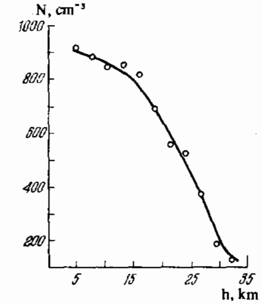

FIG. 2.

1972, which were performed on three consecutive circuits of the satellite about the Moon, the surface at the point of contact of the ray was illuminated by the rising Sun (the zenith angle of the Sun was ~ 89°). In all three cases, a regular increase in $\Delta\psi$ was observed as the instant of optical occultation was approached. This indicates the existence of a plasma in the circumlunar space over the illuminated surface of the Moon. Averaging and smoothing of the results of these measurements and subsequent solution of the inverse problem made it possible to obtain the electron-concentration distribution N(h) with respect to the altitude above the surface of the Moon (Fig. 2). As we see from the graph of N(h), the electron concentration has the highest value of ~ 900 cm^{-3} at altitudes of 5—10 km, and declines monotonically with distance from the Moon's surface to attain values comparable with the errors of measurement at an altitude of ~ 30 km. The problem of the N(h) distribution in the range 0—5 km requires additional treatment, and as yet remains open.

[1]N. A. Savich, Radiotekhn. i Élektron. 12, 606 (1967).
[2]N. A. Savich and D. Ya. Shtern, ibid. 14, 1481 (1969).
[3]M. A. Kolosov, N. A. Savich, et al., Kosm. Issl. 8, 735 (1970).
[4]M. A. Kolosov, N. A. Savich, et al., Radiotekhn. i Élektron. 18, 110 (1973).
[5]M. A. Kolosov, O. I. Yakovlev, et al., ibid. 17, 2483 (1972).
[6]A. J. Kliore et al., Science 175, 313 (1972).
[7]M. B. Vasil'ev, A. S. Vyshlov, et al., Dokl. Akad. Nauk SSSR 212, No. 1 (1973).