INVESTIGATION OF THE PROPAGATION OF DECIMETER RADIO WAVES IN THE ATMOSPHERE OF VENUS BY MEANS OF THE AUTOMATIC INTERPLANETARY STATION "VENERA-4"

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INVESTIGATION OF THE PROPAGATION OF DECIMETER RADIO WAVES IN THE ATMOSPHERE OF VENUS BY MEANS OF THE AUTOMATIC INTERPLANETARY STATION "VENERA-4"

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During the motion of the automatic interplanetary station "Venera-4" in the atmosphere of Venus, radio sounding of the entire thickness of the planet' s atmosphere was carried out with radio waves in the range $\lambda = 0.3$ m. This made it possible to determine the field strength and fluctuations of the amplitude of the radio waves when the transmitter was located at various heights above the surface of the planet. The signals were received over two independent channels, which made it possible to eliminate the influence of the ground-based apparatus on the measurements of field strength. To record the field strength, the signals were recorded on motion-picture film at a transport speed of 1 cm/sec.

At altitudes of $6000 \div 100$ km above the surface of the planet, no changes in field strength due to the ionosphere of Venus were observed. During the motion of the descent vehicle in the troposphere of the planet, a slight decrease in the mean field strength was recorded. Figure 1a gives the results of measurements of the quantity E/E_0—the field strength E, averaged over 6-minute intervals and normalized to the strength E_0 for an altitude of 26 km. The value of E/E_0 at the moment of contact with the surface of Venus was 0.76. Telemetric data on the supply voltages and the temperature regime inside the descent vehicle showed that they were within the prescribed limits; because of these factors the field strength could have changed only slightly—to a value of $0.83 \div 0.91$. Taking this correction into account, we obtain that the true value of the field strength is $E/E_0 = 0.92 \div 0.84$. The value $E/E_0 = 0.92$ is more probable; therefore the attenuation of the radio waves that passed through the troposphere of Venus is $8 \div 5\%$ in field strength.

To investigate fluctuations of the radio waves, the signal records were subjected to statistical processing. In doing so, the influence of noise and variations in the gain of the receiving path was carefully analyzed and excluded. In addition to

Figure 1

Figure 1: Figure 1

rapid fluctuations of the signal level, slow variations caused by the troposphere of Venus were observed. As a result of the scintillation analysis, the quantity $\eta_1 = \sqrt{\langle (E_i - E_{\text{cp}})^2 \rangle / E_{\text{cp}}^2}$ was obtained for different heights h of the source above the surface of the planet. The parameter η_1 characterizes the mean deviation of the instantaneous values of the field strength E_i from the mean values E_{cp}, found over 5-second intervals. The resulting set of values of η_1 was then further averaged over 2–5-minute intervals.

Figure 1b shows the dependence of η_1 on the altitude h. It follows from it that the scintillation depth increases as the source of the radio waves is immersed in the troposphere of Venus, and at its surface is equal to 0.12. The scintillation period is close to 1 sec. The scintillation depth characterized by the quantity η_1 gives somewhat underestimated values of the fluctuations of the field strength, since short realizations of the dependences $E(t)$ were used in the processing.

To estimate the influence of the interplanetary medium and the Earth' s atmosphere, the value of η_1 was determined during the pre-landing radio-communication session; the scintillation depth was then about 0.02. In Fig. 1b this quantity is shown conventionally for the altitude $h = 40$ km. The presence of radio-wave scintillations indicates

Fig. 1. Dependence of the field strength (a) and scintillation depth (b) on altitude above the surface of Venus

turbulence in the troposphere of Venus. According to Fig. 1b, the planet' s troposphere is turbulent up to altitudes L of the order of 20 km. Slow variations of the field strength may be due both to the influence of the Venus atmosphere and to the swinging of the descent vehicle. The mean depth of the slow variations at the surface of the planet is $\eta_2 = \Delta E / E_{\text{av}} = 0.24$. The quantity η_2 gives somewhat overestimated values of the depth of the slow fluctuations caused by the planet' s troposphere, since the rocking of the descent vehicle could have affected its determination. The conventional period of the slow fadings is of the order of 40 sec. The separation of fluctuations into rapid scintillations and slow variations is conventional; therefore, for the fading depth it is more objective to take the mean value $\eta = 0.18 \pm 0.05$.

The measured parameters of the fluctuations make it possible to carry out approximate estimates of the inhomogeneity of the refractive index of the troposphere of Venus. In the propagation of radio waves through a statistically inhomogeneous layer of thickness L, the fading depth η is determined by the relation (1):

$$\eta^2 = \frac{\sqrt{\pi}}{2} k^2 \overline{\mu^2} a L \left(1 - \frac{1}{D} \operatorname{arc\,tg} D\right). \tag{1}$$

Here k is the wave number, a is the mean scale of the inhomogeneities, $\overline{\mu^2}$ is the mean square of the fluctuations of the refractive index, and $D = 4L/ka^2$. If diffraction of the random field on the path from Venus to the Earth is neglected, then expression (1) makes it possible to estimate the parameter of refractive-index inhomogeneities $\overline{\mu^2}$ from the values found for η and L. To determine the numerical value of $\overline{\mu^2}$, it is necessary to make an assumption about the magnitude of the scale of the inhomogeneities a. The mean scale of refractive-index inhomogeneities in the Earth' s troposphere that give rise to fluctuations and scattering of ultrashort waves is of the order of 50 m. Taking $a = 50$ m for the troposphere of Venus, and also assuming, on the basis of the experiment, $L = 20$ km and $\eta = 0.18$, we find $\sqrt{\overline{\mu^2}} = 15 \cdot 10^{-6}$. In the Earth' s troposphere $\sqrt{\overline{\mu^2}} \approx 10^{-6}$. Consequently, in the troposphere of Venus the fluctuations of the refractive index are on average 10 times greater than in the Earth' s atmosphere.

In conclusion it should be noted that the data presented on the degree of inhomogeneity of the refractive index of the Venus atmosphere have the character of approximate estimates. For a more accurate determination of the parameter $\sqrt{\overline{\mu^2}}$, it is necessary to consider the fluctuations with allowance for turbulence having a Kolmogorov–Obukhov spectrum, and to take into account the sphericity of the wave. Taking these factors into account leads to insignificant differences in the determination of the parameters of refractive-index inhomogeneities.

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CITED LITERATURE

1. L. A. Chernov, *Wave Propagation in a Medium with Random Inhomogeneities*, Moscow, 1958.

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