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Abstract

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Academician V. A. KOTELNIKOV, L. V. APRAKSIN, V. M. DUBROVIN, M. D. KISLIK,
B. I. KUZNETSOV, G. M. PETROV, O. N. RZHIGA, A. V. FRANTSESSON, A. M. SHAKHOVSKOI

RADAR OBSERVATION OF THE PLANET JUPITER

During September–October 1963, radar observation of Jupiter was carried out in the USSR ([1]). For the radar experiment, one of the oppositions was chosen, when Jupiter approaches the Earth to within 590–600 million km. The purpose of this experiment was to study the reflecting properties of Jupiter' s surface and to investigate the propagation of radio waves over ultralong distances.

During the observations of Jupiter, the radio signals had to travel a path 6–7 times longer than in radar observations of Mars and Mercury, and 15 times longer than in radar observations of Venus during the period when it approaches closest to the Earth. Therefore, although the sensitivity of the receiving installation had been increased by a factor of 2–2.5, detecting the reflected signals was considerably more difficult than in observations of Mercury and Mars, not to mention observations of Venus.

Radio signals at a frequency of about 700 MHz were transmitted toward Jupiter. Over the entire visible surface of the planet there fell 13 W of power radiated by the transmitter. To travel the entire path from the Earth to Jupiter and back to the Earth, the radio signals required on average 1 hour 06 minutes. After this time the transmitter was switched off, and reception of the reflected signals was carried out with the aid of a second antenna on which the receiver was installed. The received signals were recorded on magnetic tape.

The transmitted signal consisted of alternating pulses and pauses at two frequencies differing by 62.5 Hz. The duration of the pulses and pauses at each frequency was 4.096 sec. The displacement of the carrier frequency and the modulation frequency of the reflected signals, caused by the Doppler effect due to the motion of Jupiter and the Earth (taking account of its rotation), was compensated according to a calculated program by means of a special device that

Fig. 1. Value of the reflection coefficient as a function of the width of Jupiter' s reflecting zone.

Figure 1: Fig. 1. Value of the reflection coefficient as a function of the width of Jupiter' s reflecting zone.

linearly varied the frequency of the receiver heterodyne. In order that the errors of linear interpolation should not be significant, the full session was divided into intervals 16 min long, in each of which a new value was set for the rate of change of the heterodyne frequency. The value 149,599,300 km was taken for the astronomical unit.

The distribution of energy in the spectrum of the received signals was investigated with the aid of a multichannel analyzer, analogous to that described in ([2,3]). The reflected signals were to appear periodically in the channels of the analyzer in accordance with the modulation of the transmitted signals. At the output of the analyzer channels, the energy of the signal and noise accumulated in those half-periods of the modulation frequency when the reflected signal should be present was determined, as was the energy of the noise alone accumulated in those half-periods when the reflected signal should be absent. The difference of these energies gives the signal energy and the residual noise energy accumulated in the given channel. To eliminate a possible error caused by interference whose repetition frequency coincides with the modulation frequency of the reflected signals, the phase of modulation of the transmitted signals was changed by half a period from session to session.

The results of the analysis of the spectrum of the signals reflected from Jupiter, accumulated over 22 hours, are presented in Fig. 1. In this graph the abscissa axis gives the width of the frequency band Δf in which the signal energy was accumulated, and the ordinate axis (on the right) gives the energy of the reflected signals in this band, converted to the power-flux density S at the receiving antenna. Near the experimental points, estimates are indicated of the root-mean-square values of the measurement errors caused by noise.

Fig. 1. Value of the reflection coefficient as a function of the width of Jupiter' s reflecting zone.

Fig. 1 shows that Jupiter causes a stronger broadening of the spectrum of reflected signals than was observed, for example, in radar observations of the planets Venus^4 and Mars^5. This is apparently a consequence of the planet' s rapid rotation about its axis, whose period according to astronomical observations is approximately 10 hours.

In Fig. 1, along the ordinate axis on the left, the values of the reflection coefficient ρ are plotted; this coefficient shows what fraction is constituted by the energy of the reflected signals received in the frequency band Δf, as compared with the energy that would be received if Jupiter were a smooth, ideally conducting sphere.

Knowing the rotation period of Jupiter and the position of its axis of rotation in space, one can calculate the width of the zone of the planet' s surface from which signals corresponding to the Doppler broadening of the spectrum Δf arrived. The width of the reflecting zone of Jupiter' s surface d is plotted at the bottom of Fig. 1. As can be seen from the figure, the reflection coefficient of Jupiter in the band studied is about 10%. In view of the fact that the complete spectrum of the reflected signals is considerably wider than the frequency band in which the energy was accumulated, the total reflection coefficient of Jupiter must be no less than this value.

Thus, Jupiter has now been added to the number of planets from which radar reflections have been obtained. A large group of engineers and technicians, headed by the Institute of Radio Engineering and Electronics of the Academy of Sciences of the USSR, took part in carrying out the radar observations of the planet Jupiter.

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Institute of Radio Engineering and Electronics
Academy of Sciences of the USSR

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