Astronomy

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Abstract

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RADIO-ASTRONOMICAL OBSERVATIONS OF THE SECOND SOVIET SPACE ROCKET

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1. The radio-interferometric method widely used in radio astronomy ($^{1-4}$) is employed for determining the coordinates of discrete sources of radio emission, for studying inhomogeneities of the ionosphere, for determining the coordinates of artificial Earth satellites, etc. This method was applied by us to observations of the radio signals of the second Soviet space rocket, which reached the Moon on 14 IX 1959. The angular coordinates of the container with scientific apparatus were measured, and also the intensity of the received signal; the character of the change in intensity with time was determined.

2. The observations were carried out at the radiation frequency of the transmitter installed in the container, 183.6 Mc/s. A radio interferometer was used similar to one already described in the literature (^{5}), with the introduction of certain nonessential changes connected with the need to narrow the radio-reception band. It is clear that if, when receiving a noise-type signal, the sensitivity of the apparatus increases in proportion to the square root of the reception bandwidth, then when receiving a monochromatic signal the sensitivity is inversely proportional to the square root of the bandwidth. We used a receiver passband of 10 kc/s. The first and second heterodynes were quartz-stabilized. At each of the two antennas, which were truncated parabolic reflectors (^{5}) with dimensions of about 200 m^2 each, there were amplifier heads with a noise factor of about 5. Reception was carried out by the phase-modulation method. To separate changes in signal amplitude caused by a change in direction to the source from changes in the intensity of the source itself, a double radio interferometer described earlier (^{6}) was used. The distance between the antennas was 175.9 m, which corresponded to an angular width of one lobe of 32′ (for normal incidence of the wave). The antennas were located approximately in the east–west direction and received a signal with horizontal polarization. Tracking of the antennas on the container and determination of the lobe number of the interference pattern (order of interference) were carried out according to pointing instructions received from the coordinate-computing center.

3. With the aid of a radio interferometer, the angle β between the direction to the signal source and the normal to the radio-interferometer baseline is measured directly. The magnitude β is determined through the lobe number n and the parameters of the interferometer by the relation

$$\sin\beta = \frac{\lambda}{D}(n-\eta), \tag{1}$$

where λ is the wavelength of the received signal; D is the interferometer baseline; η is a parameter determined by the difference in electrical lengths from each

from the antennas to the point where the signals were combined. For equal electrical lengths $\eta = 0$.

The azimuth of the source A is related to the angle β by the relation

$$\sin\beta = \sin\gamma\cos z + \cos\gamma\sin z\sin(A-\theta), \tag{2}$$

where z is the zenith angle of the source; $\gamma = 2^\circ 44'$ is the angle between the horizontal plane and the projection of the baseline onto the vertical plane passing through the east-west line; $\theta = -14'$ is the angle between the east-west line and the projection of the baseline onto the horizontal plane.

Then

$$A = \theta + \arcsin\left[\frac{1}{\cos\gamma\sin z}\frac{\lambda}{D}(n-\eta) - \tan\gamma\cot z\right]. \tag{3}$$

Of the five parameters ($\gamma, \theta, D, \lambda$, and η) entering relation (3), one parameter, γ, is determined by the radiation frequency with a correction for the Doppler effect. The other three, λ, θ, and D, which are constants, were determined by a geodetic survey of the relative positions of the antennas and were refined by adjustment. The parameter η, which depends on the electrical lengths of the cables and on the phase characteristics of the input stages, may vary with time and therefore was determined before each observation.

The adjustment of the radio interferometer was carried out using strong cosmic radio sources Cygnus A, Taurus A, and Virgo A, for which the adopted equatorial coordinates (epoch 1959.5) and radio fluxes p are given in Table 1.

Table 1

Source	$p_{183.6}$, $\mathrm{W \cdot m^{-2} \cdot Hz^{-1}}$	$\alpha_{1959.5}$	$\delta_{1959.5}$
Cygnus A	$70 \cdot 10^{-24}$	$19^h58^m05^s$	$+40^\circ 36'.5$
Taurus A	$18 \cdot 10^{-24}$	$5^h32^m09^s$	$+21^\circ 59'$
Virgo A	$9 \cdot 10^{-24}$	$12^h28^m47^s$	$+12^\circ 34'$

Fig. 1. Interferometric recording of the signal during the approach of the container to the Moon. A—the moment of signal cessation

Figure 1: Fig. 1. Interferometric recording of the signal during the approach of the container to the Moon. A—the moment of signal cessation

4. Reliable reception of the signal during the approach to the Moon up to the moment of impact made it possible to determine accurately the time of impact with the lunar surface and the region in which the container with the scientific apparatus fell. A copy of the interferometric recording of the signal on the final segment of the trajectory for one of the receiving channels is shown in Fig. 1. At the moment when the signal ceased, the sinusoidal character of the record, caused by interference, was replaced by an exponential decay caused by the cessation of the signal and the presence of a time constant. This transition is clearly visible (Fig. 1, point *A*) and determines the time of cessation of the signal as 0 h 02 min 22 s ±1 s (14 IX 1959).

Fig. 1. Interferometric recording of the signal during the approach of the container to the Moon.
A—the moment of signal cessation

Taking into account the propagation time of the signal from the Moon to the Earth, equal to 1.2 s, this corresponds to the time of impact of the container with the lunar surface, 0 h 02 min 21 s ±1 s.

The time of disappearance of the signal (0 hr 2 min 22 sec) corresponds to the number of the petal $n = 53.43$. For this value the curve $A(z, n)$, calculated by formula (3), crosses the visible disk of the Moon.

When converted to selenographic coordinates, taking into account the measurement error (equal to $\pm 1'$ when several readings are averaged), this line is transformed into the region shown in Fig. 2 by hatching.

Taking into account the data obtained by the automated measuring complex (8), it should be considered that the region of the "impact" of the container with the scientific apparatus is the region indicated in Fig. 2 by double hatching. The selenographic coordinates of the center of this region are as follows: latitude +30°, longitude −3° (Archimedes crater).

Fig. 2. Impact of the container. Single hatching—radio-interferometer data. — data of the automated complex (8); double hatching—the region of the container "impact." Coordinates are selenographic.

5. The intensity of the received signal was determined by comparison with the known radiation of the cosmic source Cygnus A. The time dependence of the change in the signal, reduced to an isotropic radiator located at the distance of the container, is shown in Fig. 3.

$$\rho = p4\pi R^2$$

Fig. 3. Time course of the change in the signal with the distance effect excluded.
a–12 IX–13 IX 1959; –13 IX–14 IX 1959.

Several characteristic periods of variation of the signal intensity were observed: a small one of about 45 sec and a large one of 45 min on 12 IX 1959, and 10–13 min on 13 IX 1959.

The presence of deep fading of the signal may be due to periodic changes in the orientation of the container and to the Faraday effect in the ionosphere.

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