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COMPARISON OF THE REFLECTION CHARACTERISTICS OF MARS IN THE 40 AND 12.5 CM WAVELENGTHS ACCORDING TO RADAR OBSERVATIONS DURING THE OPPOSITION IN 1963

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S U M M A R Y

The results of this work have been presented to the 5th All-Union Conference on Radioastronomy, held in Khar'kov in October 1965.

As was shown by radar observations of Mars in decimeter waves, the basic reflection back to locator is given by the regions near the center of the planetary disk. This allows us to compare the reflectivity of separate regions of the surface of Mars.

It is found that the dependences of reflectivity on the longitude of the central meridian at wavelengths of 40 and 12.5 cm are correlated. The value of the correlation factor for the data obtained in these wavelengths in 1963 is + 0.46.

The mean reflection factor of the Martian surface at wavelengths longer than 40 cm is about 0.07, which corresponds to the mean value of the dielectric constant 3.0. The radar observation data failed to provide any indication on the presence of water on the surface of Mars.

Author

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* *

A large number of works have been devoted to the investigation of the reflection characteristics of planet Mars in the optical band. The results of the first radar observations of Mars conducted during the opposition of the year 1963 in the 40 and 12.5 cm wavelengths, allow us to make a comparison of this planet's reflection characteristics in radioband also.

1. DIRECTIVITY OF THE REVERSE REFLECTION

In optics during the true opposition of Mars the brightness of surface details at the center and near the limb of the planetary disk remains about identical [1]. As was shown by radar observations of [2, 3], contrary to optics, the intensity of the return reflection of radiowaves by Mars' surface is sharply dependent on the incidence angle. Although the density of the incident flux within the bounds of the solid angle occupied by the planet was constant, the basic reflection back to locator was given by the regions located at that time near the center of the planetary disk.

The dimension of the zone of intense reflection was estimated by the widening of the spectral line of the sounding signal, determined by the rotation of Mars. The diameter of this zone in planocentrical coordinates in the 40 cm wavelength was found to be no more than 0.2° and at 12.5 cm, near 6°. The relatively small dimensions of the zone allow us to compare the reflectivity of separate regions of Mars" surface, passing near the reflection center as a consequence of planet's rotation.

TABLE 1

Variation of Radar Albedo from the Longitude of the Central Meridian. $\lambda = 40$ см

Longitude of the Central Meridian	Albedo	Root-mean square error	Longitude of the Central Meridian	Albedo	Root-mean square error
305--315°	0.16	±0.12	45-- 55°	0.05	0.07
315--325°	0.09	0.10	55-- 65°	0.11	0.07
325--335°	0.06	0.10	65-- 75°	0.03	0.07
335--345°	0.10	0.12	75-- 85°	0.08	0.06
345--355°	0.10	0.065	85-- 95°	—0.07*	0.07
355-- 5°	0.12	0.075	95--105°	0.00	0.075
5-- 15°	0.08	0.065	105--115°	—0.01*	0.085
15-- 25°	0.09	0.085	115--125°	0.19	0.075
25-- 35°	0.18	0.07	125--135°	—0.02*	0.085
35-- 45°	0.04	0.065			

* Because of the great weight of random errors, the points vanished.

TABLE 2

Same with $\lambda = 12.5$ см (according to data from the graph of [3])

Longitude of the Central Meridian	Albedo	Root-mean square error	Longitude of the Central Meridian	Albedo	Root-mean square error
5-- 15°	0.019	125--135°	0.019	245—255°	0.064
15-- 25°	0.033	135--145°	0.026	255—265°	0.055
25-- 35°	0.031	145--155°	0.035	265—275°	0.062
35-- 45°	0.023	155--165°	0.032	275—285°	0.071
45-- 55°	0.018	165--175°	0.015	285—295°	0.057
55-- 65°	0.019	175--185°	0.023	295—305°	0.039
65-- 75°	0.015	185--195°	0.015	305—315°	0.026
75-- 85°	0.021	195--205°	0.050	315—325°	0.012
85-- 95°	0.025	205--215°	0.019	325—335°	0.023
95--105°	0.010	215--225°	0.033	335—345°	0.035
105--115°	0.031	225--235°	0.039	345—355°	0.031
115--125°	0.039	235--245°	0.043	355— 5°	0.044

The root-mean square error is everywhere equal to ±0.01.

2. CORRELATION OF THE REFLECTIVITY

During the period of observations in 1963, the reflection center was situated in the Northern hemisphere and it shifted along the parrllel corresponding to about 14° aerographic latitude. The variation of reflectivity along this parallel in the 40 and 12.5 cm waves as a function of central meridian's longitude is shown in Tables 1 and 2, in which is given the Mars' reflection factor (radar albedo), i.e. the ratio of the observed energy density of radiowaves reflected toward the locator to the energy density of radiowaves that would have taken place if Mars were an ideally conducting mirror sphere.

The value of the radar albedo has been averaged by longitude; the averaging interval is 10°. Compiled in the tables is also the value of random errors caused by fluctuation noises of the receiving devices, which was determined in the absence of echo-signal at receiver input.

The variation of radar albedo in the 40 and 12,5 cm wavelengths with the longitude of the central meridian is plotted in Fig. 1 (the scale of the curves differs by two times). In order to diminish the sharp overshootings caused by random errors, smoothing out was performed by five points [4]*.

As may be seen from Fig.1, there exists a specific dependence between the two curves. Obviously, this dependence is determined by a concurrent variation of Mars's surface reflectivity in both wavelengths. No overlapping by the time of the day took place between observations, for the points, from which the location was conducted, were disposed in different Earth's hemispheres. This is why the interplanetary medium, or, say, the Earth's ionosphere, the variations of which are not connected with the rotation of Mars, can not be the cause of the observed dependence (even if the electron density of the interplanetary medium was sufficient to influence the propagation of decimeter waves).

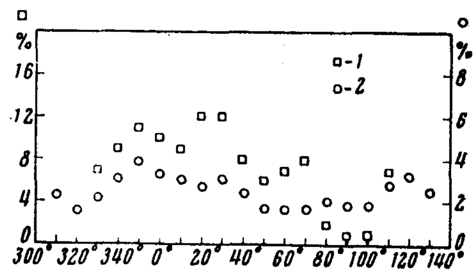

Fig. 1. Variation of Mars' radar albedo at 40 and 12.5 cm as a function of the longitude of the central meridian : $1-\lambda=40$ см; $2-\lambda=12.5$ см

In order to determine the degree of mutual relationship by 19 nonsmoothed points of Table 1 (x_i) and Table 2 (y_i) we computed the random correlation factor

$$r=\frac{\sum_{i=1}^{19}(x_i-a_x)\cdot(y_i-a_y)}{\left[\sum_{i=1}^{19}(x_i-a_x)^2\sum_{i=1}^{19}(y_i-a_y)^2\right]^{1/2}}$$

where

$$a_x=\frac{1}{19}\sum_{i=1}^{19}x_i;\qquad a_y=\frac{1}{19}\sum_{i=1}^{19}y_i.$$

The value of the correlation factor was found to be +0.46. The true correlation factor may be higher, for the nonidentical dimensions of reflecting zones in both wavelengths and the influence of random errors must diminish the correlation.

The reliability of the revealed dependence may be characterized by the probablity of the fact that the random correlation factor will attain or exceed the value of +0.46, if the processes themselves are independent. The estimate of the probability of this event for two random processes having a normal distribution for a given selection (19 points) constitutes 2.5 percent [5].

3. MEAN VALUE OF THE ALBEDO. DISCUSSION OF RESULTS.

The mean value of Mars' radar albedo during observations at 40 cm was obtained [2] equal to 0.07. This quantity is apparently maintained also for longer waves. Thus, according to the reliminary communication relative to observations at 70 cm, conducted already during the 1965 opposition, the radar albedo of Mars in this wavelength varies from 0.03 to 0.12 [6].

For a uniform mirror sphere the value of the radar albedo coincides numerically with the mirror reflection factor (by energy) for a surface material at normal wave incidence. If the material of planet's surface is an ideal dielectric, the value of the reflection factor 0.07 corresponds to the dielectric constant 3.0. This average result refers to clear regions of Mars, observed in the 40 cm wavelength (longitude 300 – 130°).

For the observations at 12.5 cm the mean value of the radar albedo was found to be significantly smaller: 0.032 for the entire series of measurements of [3] and 0.025 for the region of longitudes were the observations at 40 cm were conducted. If we exclude the possibility of errors in the calibration of the mean level of echo-signals, the decrease of albedo may suggest the inhomogeneity of the upper layer of the Martian surface in depth, or the presence of numerous relief inequalities that smooth out for a shorter wave the sharpness of the variation of the dielectric constant at passing from free space to the surface.

The presence of tiny unevennesses may be the cause of reflection zone widening observed at 12.5 cm. If indeed the average dimension of unevennesses is commensurate with the length of this wave, the intensity of the return reflection from such unevennesses at 40 cm will be substantially less than at 12.5 cm. The insufficient apparatus' response at 40 cm probably did not allow to detect these weak reflections.

Radar observations do not provide indications on the presence on the surface of Mars of water in liquid state, though near center, Sun's reflections were situated almost in the very zenith and the temperature of the surface there could be higher than 0° C, according to Pettit measurements [7]. If during the period of location substantial space of Mars's surface were occupied by water or moist soils, because of water's high dielectric constant the value of the reflection factor would approach the unity. The small value of the reflection factor does not contradict the contemporary concepts, according to which water would sublimate under the conditions of dry and rarefied atmosphere of Mars, by-passing the liquid phase.

Because of planet's axis inclination to the orbit plane, the areographic latitude of the center of reflection varies between major oppositions within the limits of ±25°. This is why, though in the course of one opposition one may investigate only a comparatively narrow band along one of the parallels, regular observations of Mars during several oppositions will allow to draw a radiochart of reflectivity of the entire Martian surface between the southern and northern tropics.

THE END

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