



---

Soviet-era science, translated into English

# Reports of the Academy of Sciences of the USSR

Academician V. A. KOTELNIKOV, V. M. DUBROVIN, B. A.  
DUBINSKY,

1963

SovietRxiv

---

View the original and related papers at <https://soviextrxiv.org/items/ru-196301.73517>

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.

## Abstract

## Full Text

Reports of the Academy of Sciences of the USSR  
1963. Volume 151, No. 3

## ASTRONOMY

Academician V. A. KOTELNIKOV, V. M. DUBROVIN, B. A. DUBINSKY,  
M. D. KISLIK, B. I. KUZNETSOV, I. V. LISHIN, V. A. MOROZOV, G. M.  
PETROV,  
O. N. RZHIGA, G. A. SYTSKO, A. M. SHAKHOVSKOY

## RADAR OBSERVATIONS OF VENUS IN THE SOVIET UNION IN 1962

It has already been reported in print that in 1962 the Institute of Radio Engineering and Electronics of the Academy of Sciences of the USSR, together with a number of organizations, carried out repeated radar observations of the planet Venus (<sup>1</sup>). The radar observations were made with the same installation (<sup>3</sup>) as in 1961, into which modifications had been introduced in order to increase the accuracy and reliability of the measurements. The sensitivity of the installation, owing to the use at the input of the receiver of a paramagnetic amplifier on a ruby crystal and to an increase in the transmitter power, was increased by approximately a factor of 6 in comparison with 1961. The frequency shift of the reflected signal, caused by the Doppler effect due to the motion of Venus and the Earth (taking account of its rotation), was compensated according to a calculated program by means of a special device that changed the frequency of the receiver heterodyne in steps of 0.2 Hz.

Every 4.096 sec the frequency of the transmitted signal was periodically changed by 62.5 Hz in order to eliminate the mean noise level in the received signal. The frequency spectrum of the signals reflected from Venus and recorded on magnetic tape was studied with the aid of a 20-channel analyzer, analogous to that used in the radar observations of Venus in 1961 (<sup>3,4</sup>).

The mean spectrum of the reflected signals for 20 sessions\*, conducted from 20 X to 21 XII 1962, constructed from the sum of the measurements at both frequencies radiated by the transmitter, is shown in Fig. 1a. The spectrum was analyzed by filters with a passband of 1 Hz. Along the abscissa in the figure are plotted the values of the tuning frequencies of the analyzer filters  $f$  relative to the frequency of the central filter  $f_0$ ; along the ordinate is the quantity  $p$ , representing the ratio of the power of the reflected signal in the band of each filter to the signal power in the band of the central filter. The dashed line indicates the value of the root-mean-square error of the measurements caused

Fig. 1

Figure 1: Fig. 1

by noise. The spectrum of the reflected signals can be approximated by an exponential (Fig. 1a)

$$p = 0.37 \exp(-0.42|f - f_0|). \quad (1)$$

The exception is the central filter, in which the signal level was greater than that given by formula (1).

The reflection coefficient of Venus\*\*, measured from the energy of the reflected signals in the 20-Hz band, varied during two months within the limits 12-18%. The energy of the reflected signals in the 1-Hz band was 2.5-3 times less than the total energy.

In 1962 the spectrum of the broadband component of the reflected signals, observed in 1961 (<sup>2</sup>), was also investigated. In this case the transmitted signal consisted of continuous periodic pulse trains whose frequencies differed by 2000 Hz, each of duration 4.096 sec. One of the radiated

\* Each session consisted of transmission and reception, the duration of which was approximately equal to the time of propagation of the signal from the Earth to Venus and back (4.5-7 min.).

\*\* The ratio of the energy of the received signals to the energy of the signals that would be received if Venus were a smooth, ideally conducting sphere.

the frequency transmitted by the transmitter did not fall within the frequency band received by the receiver. The passband of the analyzer filters in the study of the broadband component was 100 Hz. The 1962 measurements indicate the very probable presence of a broadband component in a 300-Hz band of approximately the same intensity as in 1961 [2], if one excludes the measurements of 18 IV 1961, when the intensity of the broadband component was several times higher than on the other measurement days in 1961. Because, in comparison with 1961, there were fewer sessions in which the type of modulation of the transmitted signals made it possible to study the broadband component, the origin of the latter could not be reliably established.

Fig. 1. *a*—Mean spectrum of the reflected signals. Filter passband 1 Hz. *b*—Distribution with range of the energy of signals reflected from Venus with frequency modulation. Filter passband 1 and 4 Hz.

To measure the distance from the Earth to Venus and the distribution of the energy of the reflected signal with range, linear frequency modulation was used in 1962. The frequency of the oscillations emitted by the transmitter was varied periodically according to a sawtooth law over 4000 Hz with a period of 1.024

sec. Owing to the use of a special circuit, very high linearity of the frequency variation was achieved. Corrections were introduced into the modulation parameters in order to compensate for the change in frequency due to the Doppler effect caused by the motion of Venus and the Earth. During reception, the heterodyne frequency of the receiver was also varied according to a sawtooth law. The start of the modulation on reception was set, relative to the start of the modulation on transmission, according to a calculated program with an accuracy of up to 0.1 msec. If the start of the modulation of the heterodyne on reception exactly corresponded to the actual arrival time of the reflected signal, the signal frequency at the receiver output was nominal. If, however, the reflected signal arrived earlier or later than the calculated moment, the signal frequency at the receiver output became higher or lower than nominal. From the displacement of the spectrum of the reflected signal and its parts, the correction to the calculated signal propagation time was determined, as well as the distribution of signal energy as a function of the range of the reflecting zone.

The mean spectrum of the frequency-modulated signals reflected from Venus, for 48 observing sessions carried out from 21 X to 21 XII 1962, is shown in Fig. 1*b*. The analysis was performed with filters having passbands of 1 and 4 Hz. On the coordinate axes in Fig. 1*b* the same quantities are plotted as in Fig. 1*a*. The frequency displacement of the spectrum, which could have been caused by a mismatch between the start of the heterodyne modulation and the arrival of the reflected signals,

heterodyning of the signal during playback of the magnetic recordings, so that in each session the maximum of the spectrum fell into one and the same filter.

At the bottom of Fig. 1*b* an axis of distance  $\Delta R$  is also plotted, on the assumption that the maximum of the spectrum corresponds to reflection from the point of Venus nearest the Earth, located at the center of the visible disk of the planet. The intensity of the reflection decreases as the distance of the reflecting zone increases; moreover, a noticeable reflection is still observed from zones located 1500 km from the nearest point of the planet, whose diameter is approximately 2/3 of the diameter of Venus. The data of Fig. 1*b* can be approximated (see Fig. 1*b*) by the hyperbola

$$p = 0.625 (f - f_0 + 0.625)^{-1}. \quad (2)$$

The period of rotation of Venus was determined by comparing the calculated width of the spectrum of the reflected signal, obtained on the basis of Fig. 1*b* for different rotation periods, assuming the structure of the surface of Venus to be isotropic, with the experimentally obtained spectral width. The observed broadening of the spectrum had to be caused by two factors: the proper rotation of Venus, which is constant, and the apparent revolution of Venus around the Earth, depending on their mutual position. The latter component can be calculated theoretically. The experimental results for the period from 20 X to 12 XII 1962 show that, if the rotation axis of Venus is perpendicular to the

Figure 2

Figure 2: Figure 2

Figure 3

Figure 3: Figure 3

plane of the ecliptic, the most probable is retrograde rotation (rotation in the direction opposite to the motion of Venus around the Sun) with a period of 200-300 days.

Fig. 2. Change in the distance between the Earth and Venus relative to the calculated value.

1  $-A = 149599000$  km, 2  $-A = 149598500$  km, 3  $-A = 149598000$  km, 4  $-A = 149597500$  km

The results of measurements of the distance between the Earth and Venus\* from the delay of the reflected signals with the frequency-modulated component are presented in Fig. 2. Here  $\Delta r$  denotes the difference between the actual and calculated values of the distance from the measuring station to the nearest point of the surface of Venus. Near each experimental point in the figure the values of the mean-square errors are indicated.

Fig. 3. Envelope of the signal reflected from Venus: *a* –channel with signal; *b* –channel without signal. 1 –receiver switched on, 2 –beginning of the reflected signal, 3 –end of the reflected signal, 4 –receiver switched off

\* The measured distance varied from 40 million km (minimum distance on 13 XI 1962, during the inferior conjunction of Venus) to 65 million km (21 XII 1962).

of the rms measurement error. In a single measurement the rms value of the instrumental error did not exceed 15 km.

In calculating the propagation time of the reflected signals, the following were adopted: astronomical unit 149,599,300 km; speed of light 299,792.5 km/sec; radius of Venus 6100 km.

The dashed lines in the figure show how the value  $\Delta r$  would change if the actual value of the astronomical unit were equal to  $A = 149\,599\,000, \dots, 149\,597\,500$  km and there were no errors in the ephemerides. For  $A = 149\,599\,300$  km the measurement results should have coincided with the abscissa axis.

The experimental points presented in the graph do not coincide with any of the computed curves, as should occur if the ephemerides of the Earth and Venus, from which the signal propagation times were calculated, contain errors. The smooth curve approximating the course of the experimental points was obtained under the assumption that the value of the astronomical unit is  $A = 149\,597\,900$  km, that the actual position of the center of Venus is displaced along the orbit by 270 km in the direction of motion (by 0.5 arc seconds in the heliocentric

Fig. 4. The word “USSR,” transmitted via Venus on 24 XI 1962.

Figure 4: Fig. 4. The word “USSR,” transmitted via Venus on 24 XI 1962.

coordinate system), and that the radius of Venus is 80 km smaller than the value adopted in the calculation.

The difference between the astronomical unit obtained by us in 1961 and the value given above is 1400 km, which lies within the tolerance ( $\pm 2000$  km) specified for the 1961 measurements <sup>(2)</sup>. If, in addition to those indicated above, other parameters of the orbit of Venus are also varied, then the value of the astronomical unit may be somewhat different. Complete processing of the data will probably make it possible, along with the astronomical unit, also to refine the ephemerides of Venus.

**Fig. 4.** The word “USSR,” transmitted via Venus on 24 XI 1962.

In Fig. 3a is presented a diagram of the envelope of the signal reflected from Venus, obtained on 24 XI 1962, when an unmodulated carrier was emitted for 4.5 min. The passband of the receiving channel before the detector (the detector was linear) was 6 Hz; the time constant of the integrating circuit after the detector was 6 sec. For comparison, Fig. 3b presents a diagram of the noise envelope in an analogous channel, shifted in frequency by 62.5 Hz, in which there was no signal.

The sufficiently high signal-to-noise ratio that occurred when Venus was near the Earth suggested carrying out radiotelegraphic communication using Venus as a passive reflector. In November 1962 the words “MIR,” “USSR,” and “LENIN” were transmitted. Fig. 4 shows the appearance of the word “USSR,” transmitted by radiotelegraph code, which traveled a total path of 85 million km.

The authors express their gratitude to L. V. Apraksin, R. S. Bondarenko, V. O. Voitov, M. M. Dedlovskii, N. M. Dmitriev, V. S. Dovgello, V. I. Krivda, V. M. Makhorin, G. A. Podoprigure, N. M. Sinodkin, G. I. Slobodenyuk, Z. G. Trunova, A. V. Frantsesson, and D. M. Tsvetkov, who participated in the preparation and conduct of the measurements.

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

Received  
20 VI 1963

## CITED LITERATURE

1. Newspaper *Pravda*, 29 XII 1962.
2. V. A. Kotelnikov, V. M. Dubrovina et al., *Radio Engineering and Electronics*, **7**, 11 (1962).

3. V. A. Kotelnikov, L. V. Apraksin et al., *ibid.*

4. V. A. Morozov, Z. G. Trunova, *ibid.*

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

*Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.*