Table 1. Radiometer characteristics.

Item and unit	Channel 1	Channel 2
Center wavelength (mm)	19	13.5
Center frequency (Gcy/sec)*	15.8	22.2
Predetection bandwidth (Gcy/sec)*	1.5	2.0
Sensitivity, rms (°K)	15	15
Calibration signals (°K)	1500	800
Time constant (sec)	40	40
Beamwidth (deg)	2.5	2.2
Side lobes (db)	−23	−23
Reference frequency (Cy/sec)	950	1050

* 1 Gcy = 1 gigacycle = 10^9 cycles.

scans follow. (The temperatures are based on calculations which account for the effects of the antenna beam and the post-detection time constant.) For scan 1 (dark side), 460°K; for scan 2 (near terminator), 570°K; for scan 3 (light side), 400°K. The errors of the quoted temperatures are estimated to be 15 percent.

The possibility of interference between the Mariner radiometer data channels is being investigated. This effect is not expected to alter significantly the tentative conclusions we have given. To date, the analysis of the preliminary results suggests that there is no significant difference in the microwave temperatures on the light and dark sides of the planet. In addition, the results suggest a limb darkening, an effect which presents cooler temperatures near the edge of the planetary disk. The ionosphere model of Venus, which permits earth-like temperatures, appears to be ruled out by these observations. On the other hand, the observed limb darkening is consistent with a model of the Venusian environment which has high temperatures originating deep in the atmosphere or at the surface of the planet.

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Notes

1. The radiometer was designed and built at the Jet Propulsion Laboratory. It was based on a larger, four-channel flight instrument developed by the Ewen Knight Corp.
2. A detailed report is in preparation.

25 February 1962

Magnetic Field

Abstract. *Mariner II magnetometer data gave no indication of a Venusian magnetic field. This implies, by comparison with spacecraft measurements near Earth and with theoretical models, that the magnetic dipole moment of Venus is at most 1/10 to 1/20 that of the earth.*

Magnetometer data, obtained as Mariner II passed Venus, gave no evidence of a Venusian magnetic field at any point on the trajectory. No rise in the average value of the magnetic field above the value of the interplanetary field was detected which could be attributed to the planet. The sensitivity of the magnetometer is such that a field change as large as about 4 gamma on any axis would have been detected. (One gamma is 10^{-5} gauss. The magnitude of the earth's field at the equator is about 30,000 gamma.) During encounter, a slow change no larger than about 10 gamma was observed. However, this change should be attributed to a temporal change in the interplanetary magnetic field because it did not have the character of a planetary field. We did not detect the continuous fluctuations with periods from 1 second to 1 minute and amplitudes of the order of 3 gamma, that seem characteristic of the interplanetary region just outside the geomagnetic field. Simultaneous measurements by other Mariner experiments also failed to reveal any effect associated with a planetary field such as trapped particles or a modification in the flow of solar plasma (*1*).

These results do not necessarily mean that Venus has no magnetic field, for the solar wind would confine a weak field to a limited region close to the planet (*2*). The observations indicate that the field does not extend out to the Mariner trajectory, for which the distance of closest approach from the center of Venus was approximately 41,000 kilometers. The results are consistent, however, with the possibility that Venus has no magnetic field.

Since the planetary field does not extend out to the Mariner trajectory, an upper limit for the magnetic dipole moment of Venus can be estimated. Theoretical models of the interaction of the solar wind with a dipole magnetic field, including a crude estimate of the extent of the disturbed region outside the magnetosphere, indicate that the dipole moment of Venus, if it is approximately perpendicular to the Sun-Venus line, is less than 1/10 that of the earth. Comparison of the measurements made near Venus with those made by other spacecraft near the earth leads us to the conclusion that the dipole moment of Venus is less than 1/10, or perhaps 1/20, that of the earth. If the dipole moment of Venus is the dominant field source, the magnitude of the surface field is less than 5 to 10 percent of the geomagnetic surface field. If Venus has a more complicated magnetic structure than the earth, so that higher-order multipoles are important, the surface field in places could be larger than the earth's field without increasing the strength of the field along the Mariner trajectory to an observable value.

Phenomena associated with the geomagnetic field, such as the trapping of particles in radiation belts and the aurora, are likely to be greatly modified, less important, or completely absent on Venus because of its weaker field. The cosmic ray flux at the top of the Venus atmosphere may everywhere correspond to the high level found on earth only in the polar regions.

The Mariner data now add Venus to the other members of the solar system whose magnetic properties are partially known. Recent interpretations of the polarized radio noise from Jupiter indicate that the magnetic field of the surface is 5 gauss (*3*). The Lunik II magnetometer showed that the surface field of the moon, on the sunlit hemisphere, is less than 100 gamma (see *4*).

Jupiter rotates rapidly, twice in an earth day, and is 10 times as large as the earth. The moon rotates once each 28 days, and astronomical observations indicate that Venus, too, may be rotating slowly. These observations suggest that planets and satellites that rotate much less rapidly than the earth have small magnetic fields. This is consistent with theories (*5*) which ascribe planetary magnetic fields to a dynamo action inside the molten core of a rotating planet (*6*).

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References and Notes

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5. D. R. Inglis, *Rev. Mod. Phys.* **27**, 212 (1955); R. Hide and P. H. Roberts, in *Physics and Chemistry of the Earth* (Pergamon, New York, 1961), vol. 4.
6. The three-axis flux gate magnetometer electronics were designed and built by Marshall Laboratories of Torrance, Calif., under the supervision of the Jet Propulsion Laboratory, represented by Benjamin V. Connor, the magnetometer project engineer. The experiment is supported by the National Aeronautics and Space Administration under contracts NASw-6 (E.J.S.), NsG 151-61 (L.D.), and NsG 249-62 (P.J.C.). The sensor was designed and fabricated by Institut Dr. Förster, Reutlingen, Germany.

25 February 1963

Rotation of Venus: Period Estimated from Radar Measurements

Abstract. *Venus may rotate in a direction opposite to that of the earth at a rate of only one revolution in 240 days. The estimated period is accurate within 20 percent if the axis of rotation of Venus is perpendicular to the plane of the planet's orbit.*

Between 1 October and 17 December 1962 we established radar contact with Venus and found that the planet may rotate in a direction opposite to that of the earth at a rate of only one revolution in approximately 240 days. The result has been checked by two independent methods, a range-gated spectrum experiment and a continuous-wave spectrum experiment. We believe this rotation period is accurate within 20 percent if the axis of rotation is nearly perpendicular to the orbit plane of Venus.

Continuous-wave spectra were obtained by transmitting a 13-kilowatt signal of frequency 2388 megacycles per second toward Venus and computing the frequency spectrum of the received echo. An 85-foot parabolic antenna was used alternately for transmission and reception. It was switched between the two modes in accordance with the time required for the signal to make a round trip. An ephemeris-controlled receiver was used to remove from the echo the Doppler shift due to the relative velocity between Earth and Venus. The transmitted signal was less than 1 cycle wide, and any broadening of the echo received was due to the relative velocity of different parts of the planet. The differences in width between the transmitted and received signals may be attributed to the apparent rotation of Venus.

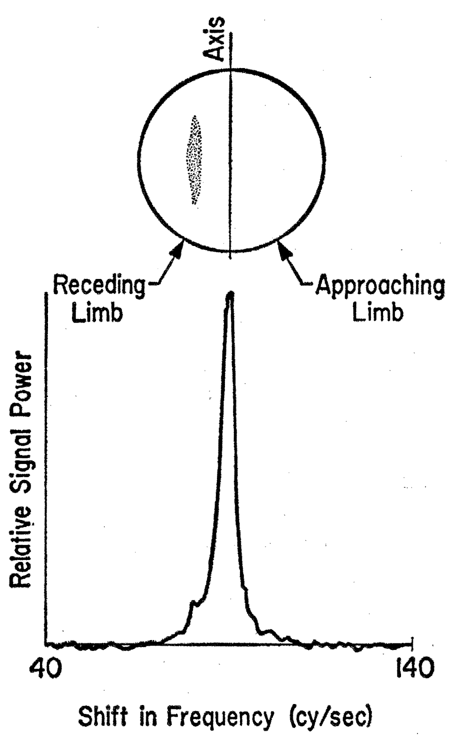

Fig. 1. Continuous-wave radar spectrum of Venus, 10 November 1962.

Figure 1 shows the spectrum obtained on 10 November 1962. It was computed on the I.B.M. 7094 computer from data recorded for about an hour. The ordinate is relative signal power (per unit bandwidth), and the abscissa is frequency shift. The plot can be interpreted equally well as signal power versus radial velocity relative to the center of the planet. The peak corresponds to zero radial velocity. The spectrum has a resolution of 1 cy/sec or a radial velocity resolution of about 6.3 cm/sec. The sketch above the spectrum shows the relation between the spectrum and the regions of Venus from which the signal may have been reflected. It is based on the important assumptions that the axis of rotation is perpendicular to the planet's orbit and that energy was received almost to the limb.

Of particular interest is the detail on the lower left side of the spectrum. At least a suggestion of a similar detail was found on all but two of the spectra obtained in the month preceding conjunction. Figure 2 shows the position of various details relative to the peak of the spectrum. The ordinate is the date of the observation, and the abscissa is the frequency difference between the peak and detail in cycles per second. The widths of the boxes correspond to the approximate width of the detail. The filled boxes are considered good identifications, while the unfilled and dotted ones are fair and poor, respectively. There is an obvious continuity in the position of the best identified details which strongly suggests that the details represent one and the same spectral detail which has moved slowly across one side of the spectrum. If this detail is the result of an actual topographic structure on the surface of Venus, then the rate at which it moves may be used to estimate the planet's rotation period. To obtain the rotation rate, the position of the detail on Venus must be known. The longitude of the detail, relative to the center of the planet's disk, may be

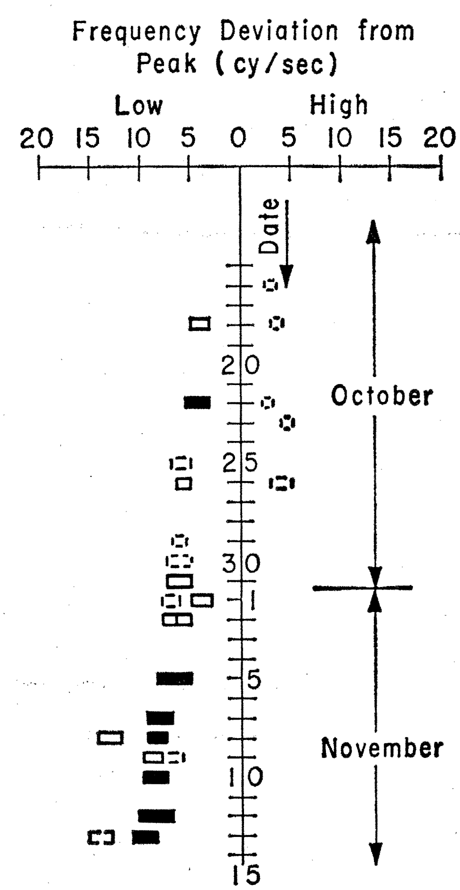

Fig. 2. Position of details on spectrum relative to the central peak. The dates read downward.