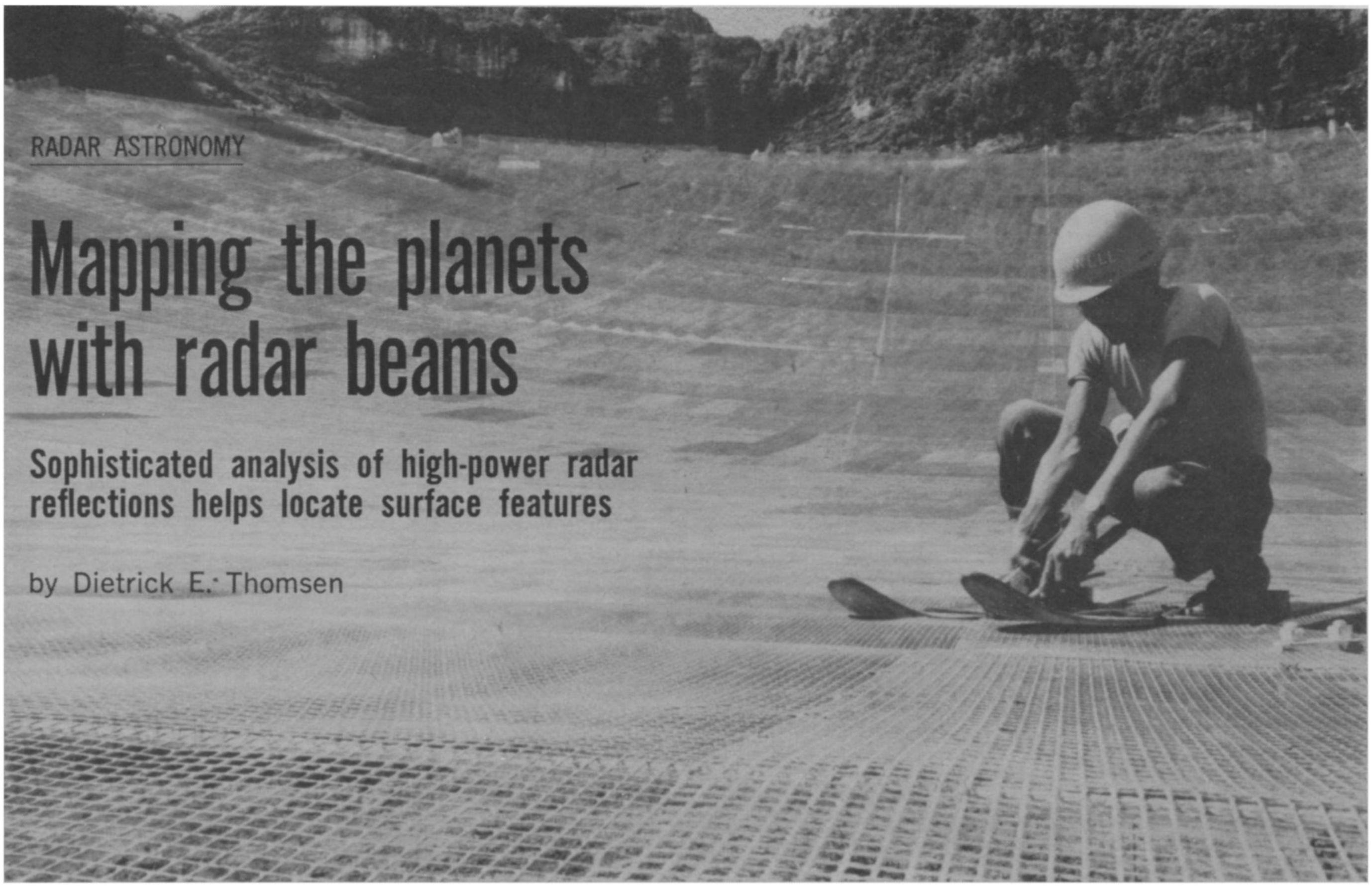
RADAR ASTRONOMY

Mapping the planets with radar beams

Sophisticated analysis of high-power radar reflections helps locate surface features

by Dietrick E. Thomsen



Gilbert & Bennett Mfg. Co.

Examining the links of Arecibo's reflecting mesh. Technician wears water skis to avoid distorting the shape.

Studying the planets by bouncing radar signals off them and back to earth is a science that demands sophisticated and expensive equipment and very clever people.

The capital cost of a radar telescope can be from slightly more to several times that of a useful radio installation with a comparable antenna, and the cost of operation can be about double. Respectable radio astronomy can also be done with antennas smaller than those needed for planetary radar work.

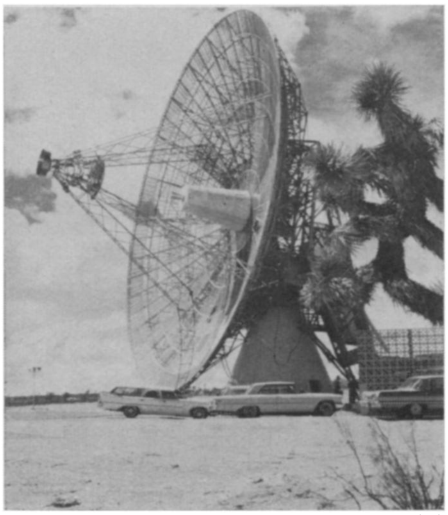
Size, cost, and the scarcity of expert personnel are some of the reasons why there are only three installations in the United States (and possibly in the world) that are achieving results in attempts to produce radar maps of the surface of Venus (SN: 2/24 p. 183). They are the 1,000-foot dish at Arecibo, Puerto Rico, the Jet Propulsion Laboratory installation at Goldstone, Calif., and two antennas of the Lincoln Laboratory located at Westford and Tyngsboro, Mass.

Both radar and radio astronomy need large antennas—in fact the same antennas can be used for both applications and often are—but radar work requires that other parts of the system be more sophisticated than some kinds of radio work need. A radio telescope simply listens to signals generated by natural processes going on elsewhere in the universe. A radar sends out its own signal and tries to investigate a distant object by analyzing the reflected return.

The required transmitters must be very powerful. Getting the signal across to, say, Venus or Mars is not enough; the reflection must come back with sufficient power to allow analysis of its characteristics, such as the amount of scattering that has taken place in the reflection, the frequency spectrum and the phase. For example, the transmitter at what the JPL people call their "Venus station" is rated at 100 kilowatts—double the power of the maximum allowable commercial transmitter. This sort of punch can be expensive; the cost of JPL's present installation is hard to estimate because it has been modified many times since it was built, but JPL estimates a transmitter of this power would cost between $1.5 and $2.5 million depending on the modulation desired for the signal.

Once the signal returns, it must be recorded and analyzed, on equipment more complex than that needed for many kinds of radio work. Radar of the Venus-mapping type must have automated data recorders with capacious memories because the information in a radar beam is more complex than that in a radio one. Analysis of the data requires further sophisticated mathematical machinery.

Antennas of equal and greater size than the mapping trio exist in fair numbers elsewhere in the United States and the world. Great Britain and Australia are especially famous for large radio dishes, but except for the U.S. efforts, only at Jodrell Bank in England, according to Dr. Philip Yeager of the Naval Research Laboratory, has an attempt at Venus mapping been made, though results have not been published. Elsewhere, it seems, organizations either do not have or do not wish to spend the money to mount the transmitting and recording equipment on their antennas.



JPL

JPL's Venus station at Goldstone.

Venus is a favorite of the radar investigators because it comes nearer the earth (26 million miles at closest approach) than any other planet, and because its cloud-shrouded surface is never visible to optical telescopes. Radar beams can reach the sun and other

planets, but what can be learned from them diminishes with distance.

The mapping technique begins by sending an unmodulated, pure tone signal to the planet and recording the reflected return signal. Rough areas scatter the radiation more than smooth ones, so if the return signal shows evidence of having been seriously scattered, the investigator knows that there is a surface feature at some point on the planet's surface.

But he doesn't know where. He can, however, analyze certain other properties of the reflected radiation that tell something about the location from which they come. According to Dr. Gordon Pettengill of Lincoln Laboratory, three complementary kinds of analysis are done and by a process of elimination the location of a particular rough spot can be determined.

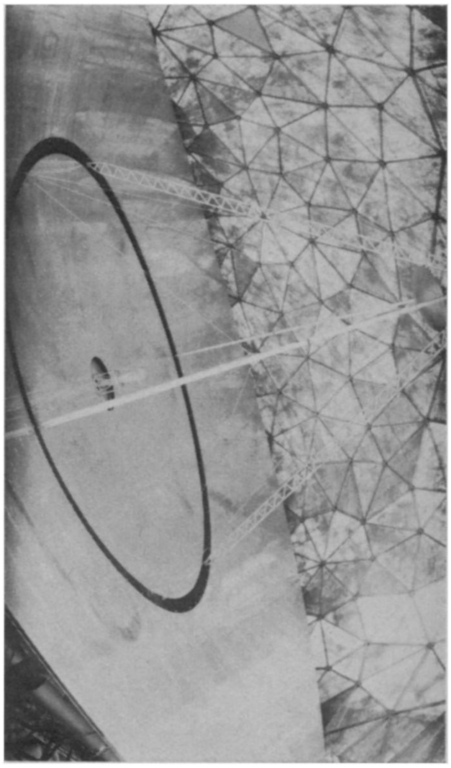
First to be analyzed is the frequency of the returned signal. Reflection from a moving object changes the frequency of the radiation in an amount proportional to the speed of the reflecting object. This is part of the Doppler effect; the technique is known as Doppler radar.

Separating the frequencies in the reflected signal from Venus distinguishes regions moving at the same speed toward or away from the observer. On the disk such regions appear as narrow strips parallel to the rotation axis, since as the planet rotates, objects at one extremity move toward the observer, those in the middle move across the line of sight, and those at the other extremity move away.

Objects that have the same velocity in the line of sight fall into fairly narrow strips across the face of the disk, and if one finds heavy scattering in the reflected signal at a given frequency, one knows that the rough spot lies somewhere in the strip the speed of which corresponds to that frequency.

The next characteristic analyzed is the time delay of the signal. Radar measures the distance to an object by the time it takes for the signal to go out and back. On a sphere the nearest point to an observer is the center of the apparent disk, the farthest away is the edge. Areas at the same distance from the observer arrange themselves in a series of concentric rings. Thus, when the astronomers find the same scattering as they had in the previous Doppler analysis, and it comes to them after a particular time delay, they know that the rough spot must lie on a particular circle in the disk. Combining the circle and the strip, they know that the rough spot must lie in one of their two intersections.

In the one-telescope technique, the same antenna is used as both sender and receiver, but in interferometric practice, where the signals received at two stations are compared, only one functions as sender. In the Lincoln Laboratory arrangement, the 120-foot Haystack dish in Tyngsboro acts as sender and receiver, while a 60-foot dish located about a mile away in Westford is used as receiver only.



Lincoln Laboratory

Haystack from inside the dome.

Interferometry is used to resolve the final ambiguity. The antennas are spaced far apart—the distance could be several miles—and the signals they receive are combined. As the antennas scan, the signals go alternately in and out of phase with each other, and a so-called fringe pattern is generated—high amplitude of signal where the two are in phase and reinforce each other and zero amplitude where they are completely out of phase and cancel. The fringe patterns are different for different antenna spacings, and recordings of many different ones are taken. Mathematical analysis of the patterns can then locate the rough spot at a particular point on the strips delineated by Doppler measurements. Or, if the time-delay analysis has already been applied, interferometry will tell which of two remaining possible points is the right one.

The three methods together give a quite reliable determination. They are usually done separately and the results combined afterward. They can be done together, Dr. Pettengill says, but only if the investigator is willing to pay the price of a high signal-to-noise ratio and consequent loss of accuracy in the determinations.