RADIO ASTRONOMY START A NEW HOBBY

POPULAR ELECTRONICS

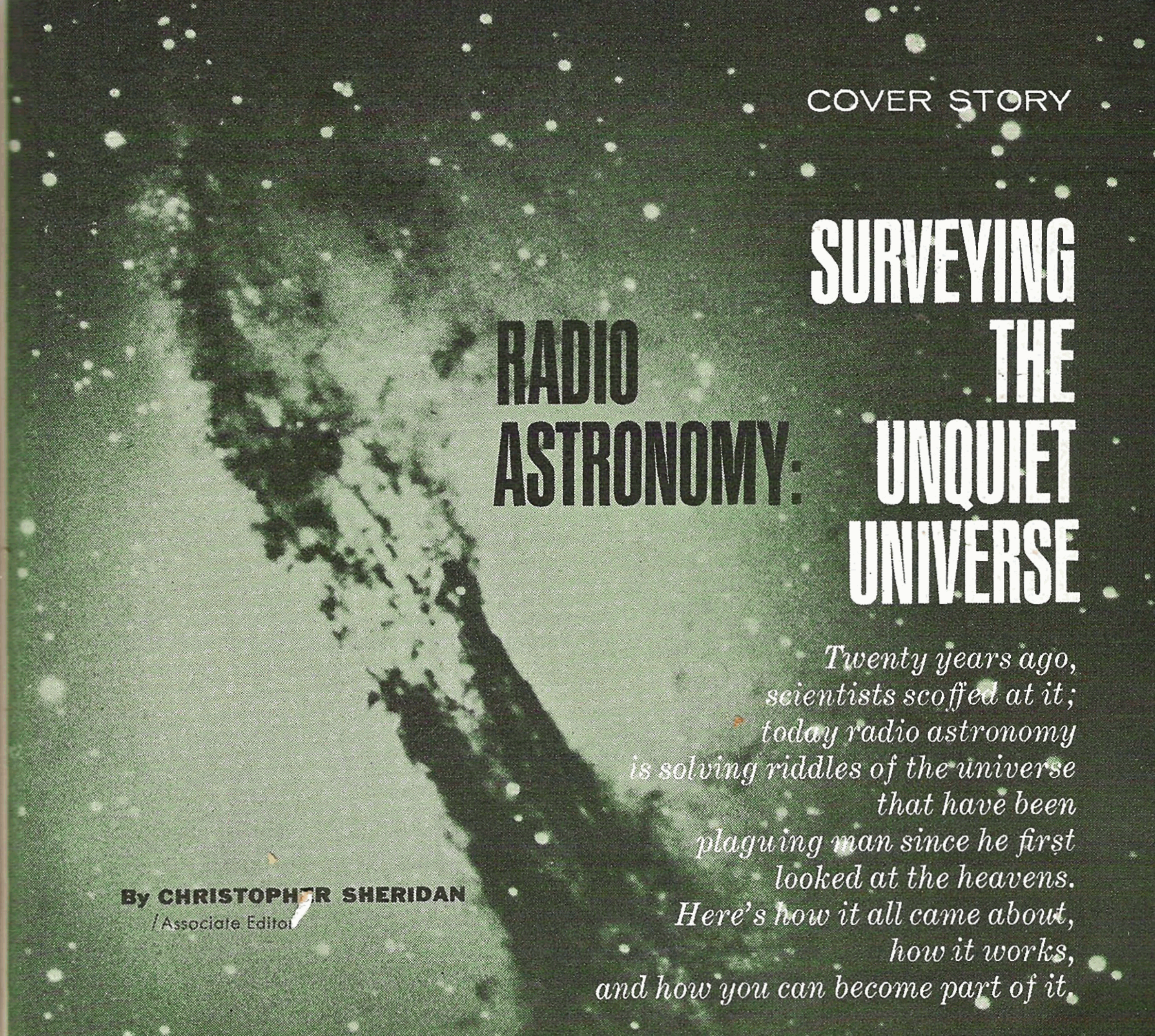
JANUARY 1966

35 CENTS

BUILD:
- Photocell Theremin
- Panic Siren
- Hi-Fi Lamps À Go-Go
- Absorption Meter
- No-Key Electrolock

MAKE YOUR OWN:
Column Speakers for Better Stereo

A ZIFF-DAVIS PUBLICATION



RADIO ASTRONOMY: SURVEYING THE UNQUIET UNIVERSE

Twenty years ago, scientists scoffed at it; today radio astronomy is solving riddles of the universe that have been plaguing man since he first looked at the heavens. Here's how it all came about, how it works, and how you can become part of it.

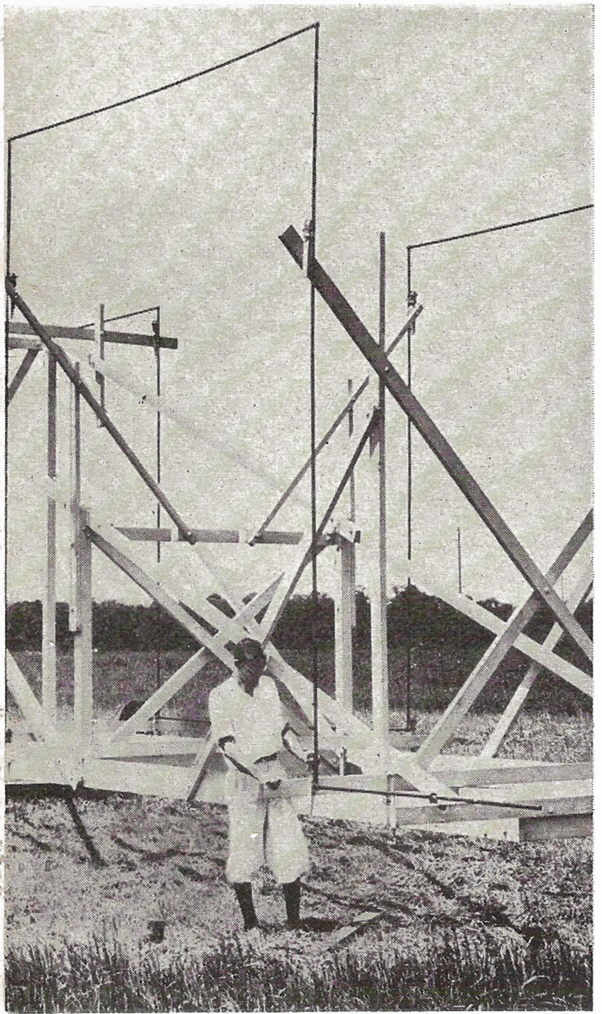
By CHRISTOPHER SHERIDAN
/Associate Editor/

IN THE SPRING of 1933 a young engineer made front-page news with the startling announcement that he had picked up signals from outer space. But few people at the time sensed the importance of such a discovery, and the man and his work fast slipped from the public eye. No one, not even astronomers, realized that the engineer, Karl Jansky, had made contact with a new universe—a radio universe.

Like many epochal discoveries, radio astronomy resulted from a single and unexpected event. In 1930, Jansky, employed by Bell Telephone Labs, was given the problem of studying static interfering with transoceanic broadcasts. He set up a rotating 100′ antenna, mounted on wheels salvaged from a Model-T Ford, on what was once a potato farm in Holmdel, New Jersey. In his investigation of static sources around 20 mc., he became aware of a different-type signal which he described as "a hiss that can hardly be distinguished from the hiss caused by set noise. . . . The term static does not quite fit it. . . . It changes direction continuously throughout the day, going completely around the compass in 24 hours."

There was really nothing peculiar about these hissing noises; radio operators had been observing them for years. But instead of dismissing them as unimportant, Jansky set out to find out where they were coming from and thereby gained immortality. It did not occur to him at first that the source could be of extraterrestrial origin, and many months of exacting observations passed before he traced the source to the constellation Sagittarius, some 26,000 light years away, smack in the center of our galaxy, the Milky Way.

The next few years were mighty lean ones for radio astronomy; still scientifically unacceptable, Jansky's work only managed to survive through the efforts of Grote Reber, an avid radio amateur (W9GFZ) from Wheaton, Illinois. Single-handedly carrying out research with a backyard 31′ parabolic dish antenna, he not only confirmed Jansky's discovery but also compiled a complete radio map of cosmic radio sources "broadcasting" on 162 mc. in the Milky Way. Another early pioneer, G.C. Southworth of Bell Telephone Laboratories, first detected radio emissions from the sun in June, 1942, at frequencies of 3000 mc. and 10,000 mc. In England, only four months before, physicist Stanley Hey had detected radio emissions associated with sunspot activity.



The "forgotten man" in the discovery of solar radio emissions is Dennis Heightman (G6DH). Heightman—tuning the bands between 25 and 60 mc.—had correlated the solar hiss with sunspot activity prior to 1940. Though Heightman reported his finding to Sir Edward Appleton, it was never recognized as predating the identical discovery by Hey.

Despite the efforts of these early pioneers, radio astronomy attracted very little attention until after World War II, when demobilized scientific minds and military developments in sensitive receivers and narrow beam antennas became available. And, it wasn't until 1947, when radio telescopes had some degree of resolution, that the first radio source—the Crab nebula, some 3300 light years distant—could be accurately pinpointed.

Today it's different. Radio astronomy has ripened into an exciting full-fledged science; there are now some 350 radio observatories throughout the world actively carrying out research. With this new tool, scientists can "see" vast regions of the heavens hitherto denied them, as optical study of our galaxy and of galaxies beyond is often blurred by huge clouds of interstellar dust. Radio astronomers have already pinpointed thousands of discrete radio sources, many of which have yet to be identified with optical objects.

Purely Natural in Origin. Radio signals from space are not as mysterious as you might think. Much is known about them—why they occur, and where they come from. Scientists discount the possibility that they are huge broadcasting stations manned by intelligent worlds; rather, they say, all celestial bodies, from our neighbor, the moon, to the furthermost known galaxy some 10 billion light years away, behave like giant transmitters, emitting vast amounts of electromagnetic energy.

Part of this energy lies in the visible portion of the spectrum, but a much greater part lies in the radio range, invisible to the eye but every bit as real as the visible wavelengths. Radio waves offer astronomers a range of wavelengths

The man who started it all, the late Karl Jansky, and his "merry-go-round" antenna at Holmdel. Today he's looked upon as the father of radio astronomy.

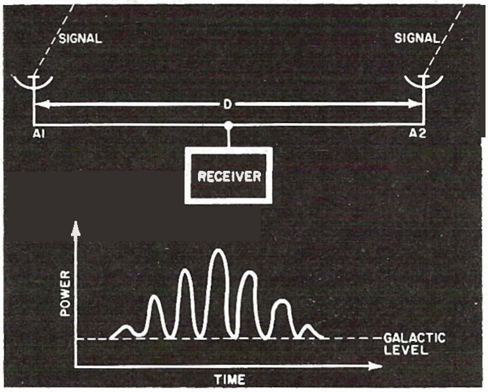
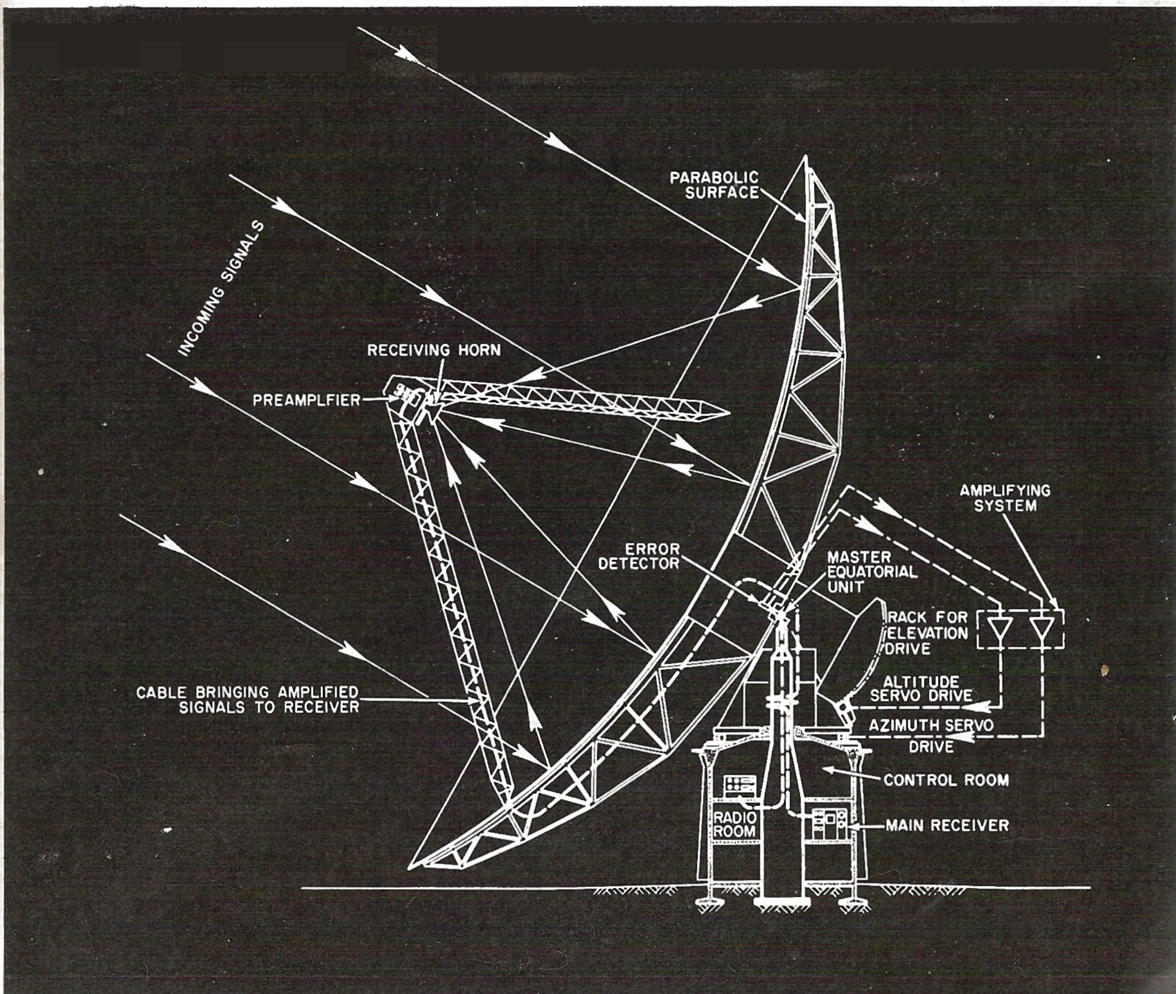


Illustration below shows a basic radiometer employing a single-aperature dish antenna. The signals are fed into a preamplifier and receiver, and the output is coupled to a recorder. Scientists in their quest for radio telescopes of greater resolution have turned from making larger and larger dishes to using an interferometer, a simplified diagram of which is shown above. The high-resolution interferometer picks up the signal on two widely-spaced antennas connected to the same receiver. The signals at each antenna either add to or subtract from each other, depending upon their phase, resulting in the response curve shown. A small source shows closer spaced lobes than a large one.

with which to "view" the universe some 10,000 times greater than the available range of optical wavelengths. With this broad spectrum available for analysis, it's easy to see why astronomers feel that the radio telescope has opened a new "window" to the universe.

All radio sources fall into two categories: thermal and non-thermal. Thermal radiation sources are called so because the intensity of radiation depends on the temperature of the source. Generally visible to the optical astronomer as well as to the radio astronomer, these sources include the solar corona, moon, planets, and galactic nebulae.

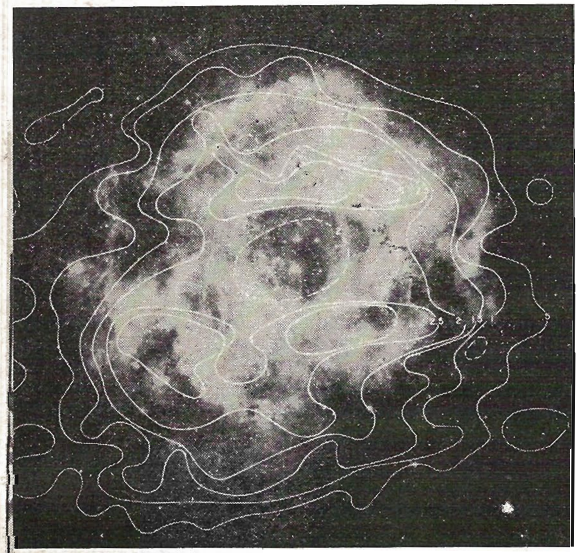
Most thermal radiation is said to be of the continuum type; one important source of thermal radiation, however, occurs on a monochromatic wavelength of 21 centimeters (1420 mc.). Called the "Hydrogen Line," it originates from clouds of cold hydrogen gas which make up a significant portion of the universe. Discovery of this important phenomenon has enabled scientists to chart the mo-



tions of huge clouds of hydrogen gas.

Unlike thermal sources, non-thermal sources do not depend on source temperature. Often referred to as synchrotron radiation, non-thermal radiation is generated by the interaction of free electrons with various magnetic fields of our galaxy. Some well known non-thermal sources include: the Crab nebula, Cassiopeia, and Cygnus A—the three most powerful radio sources yet discovered. All three emit signals on many frequencies below 10 mc. to way above 10,000 mc. Cygnus A, a half billion light years away, is the strongest source—the energy emitted by this one source alone in just one millionth of a second could supply all the world's electrical power requirements a million times over for the next 10 million years.

Most radio sources "broadcast" with



An isophote or contour map of the Rosette nebula super-imposed on an optical picture. Note similarity. Lines of isophote join points of equal temperature.

tremendous energies, often as much as 10^{35} watts or more (10^{6} watts is 1,000,000 watts). Because these sources are so distant from the earth, however, the power dwindles to around 10^{-7} of a watt or less by the time it reaches us. Most extragalactic radio sources are galaxies and are classified as "normal" or "radio" galaxies. Although both types look the same through a telescope, radio galaxies (e.g., Cygnus A) emit radio signals at energies more than one million times that of normal galaxies (e.g., Andromeda).

Most recently, radio astronomers have discovered a number of mysterious star-like sources of fantastic radio energy billions of light years away. Called quasi-stellar or quasars, their erratic behavior may eventually give answers to the origin of the universe.

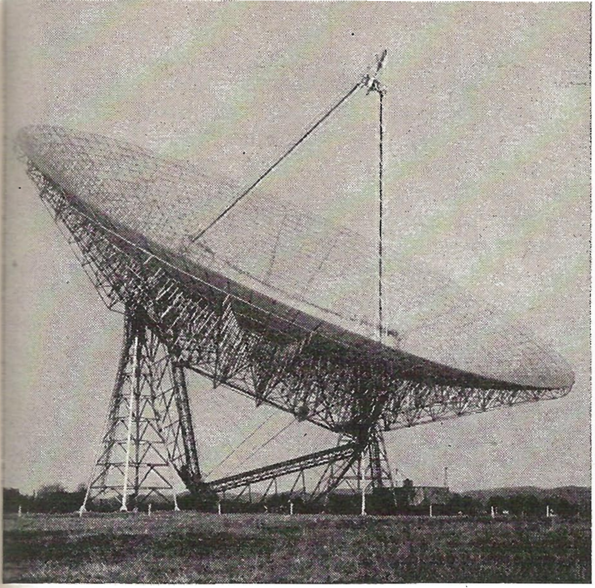
Tuning in the Solar System. The sun, only eight minutes away from earth by the speed of light or radio waves, is the most studied radio source. Radio emissions from it, characterized by a background of radiation (quiet sun) upon which are imposed bursts caused by sunspots and noise storms, occur at frequencies between 20 and 30,000 mc. Sunspot emissions can be picked up between 50 and 1000 mc. and are usually 100 times as intense as quiet sun emissions; noise storms broadcast at tremendous intensities, sometimes as high as 10,000 times quiet sun emissions, and can be picked up at frequencies between 20 and 300 mc.

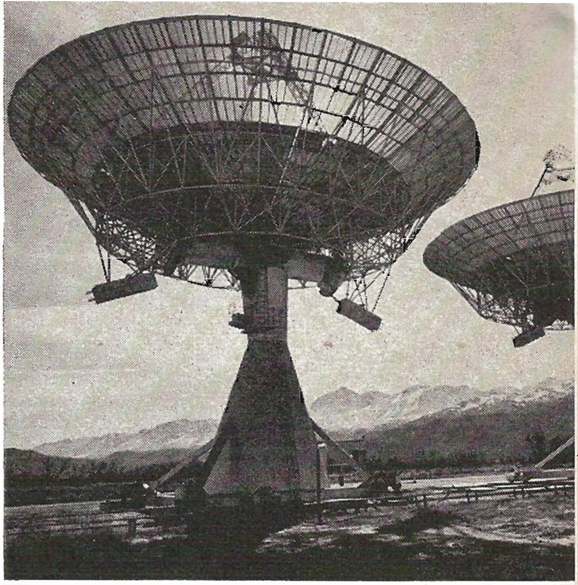
Other "broadcasting stations" in our solar system include the moon and most planets; frequencies most used in planetary radio astronomy range from 5 mc. to 75,000 mc. Interpolation of radio data from these close-to-home sources has led to many unexpected and valuable discoveries. Scientists can tell much about the surfaces, temperatures, and atmospheres of these sources.

Lunar signals were first detected on 24,000 mc. by American scientists Dicke and Beringer in 1945. These signals, which occur on many frequencies between 20 mc. and 25,000 mc., are a combination of second-hand waves emitted by the sun and bouncing off the moon, and true lunar signals generated beneath the moon's surface. Peak intensity of these signals occurs at least three or four days after full moon.

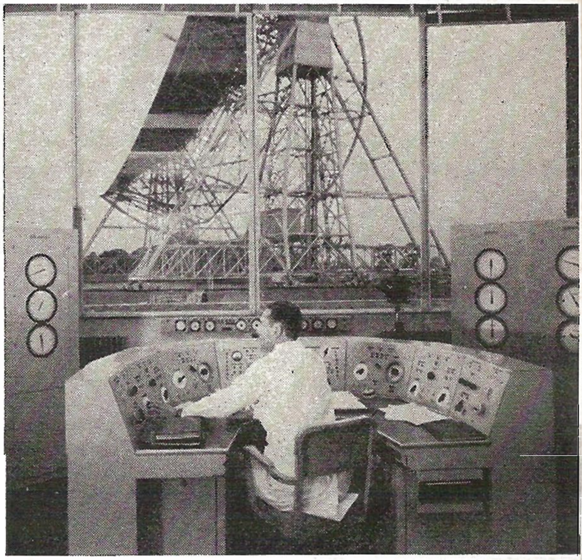
Signals were first detected from Venus, Mars, and Jupiter in 1956. Radio observations of Venus, usually made on frequencies between 400 and 10,000 mc., have shown the planet to have an extensive atmosphere and high surface tension. Signals from Mars are usually picked up at frequencies above 2500 mc.

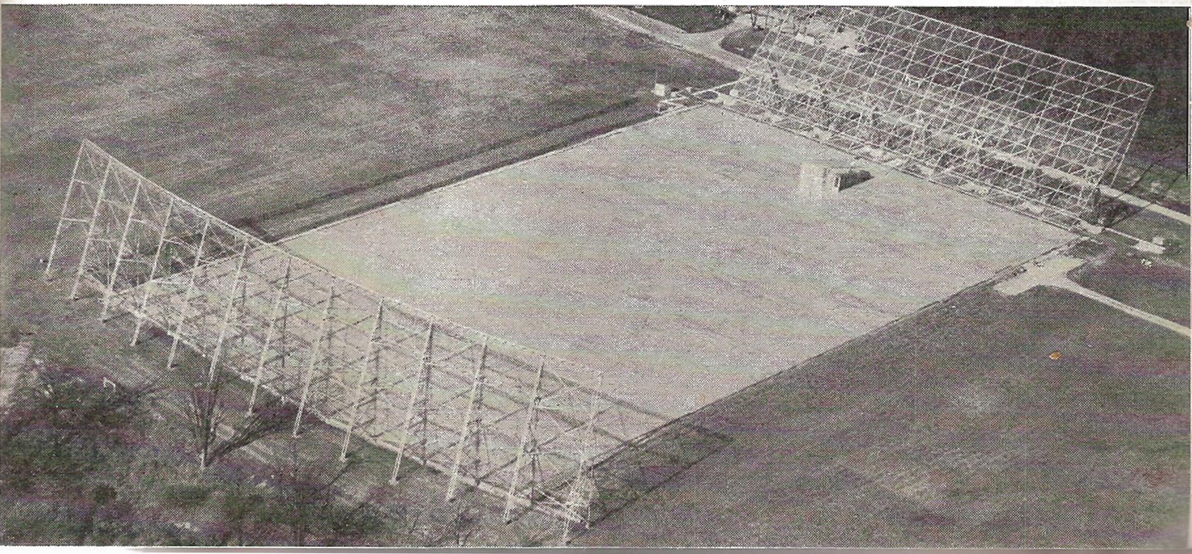
Jupiter, one of the strongest radio sources ever found, has three types of emissions: very high frequency radiation





The photos on this page, left to right, clockwise, show installations at the National Radio Astronomy Observatory, Green Bank, West Virginia; the Owens Valley Observatory, California Institute of Technology, Pasadena, California; the control console at Jodrell Bank, England; and the Ohio State University telescope. The 300′ radio telescope at the National Radio Astronomy Observatory, the largest partially movable unit in the world, is currently measuring hydrogen in this and other nearby galaxies. Twin 90′ dishes operate together as an interferometer at Owens Valley. Rails move them up to 1600′ apart, or they may work independently. Operating at 960 mc., this installation is currently being used to chart the distribution of radio noises in our galaxy. The largest fully steerable unit in the world, the 250′-diameter dish at Jodrell Bank, can receive and transmit wavelengths from a few centimeters to 20 meters. All telescope motions are controlled from a console located some 200 yards from the main telescope. The Ohio State tiltable reflector uses a 260′ by 100′ flat reflector to reflect energy onto a 360′ by 70′ fixed parabolic section. A feed horn located on the ground plane near the base of the flat reflector receives radio signals from the parabolic section.

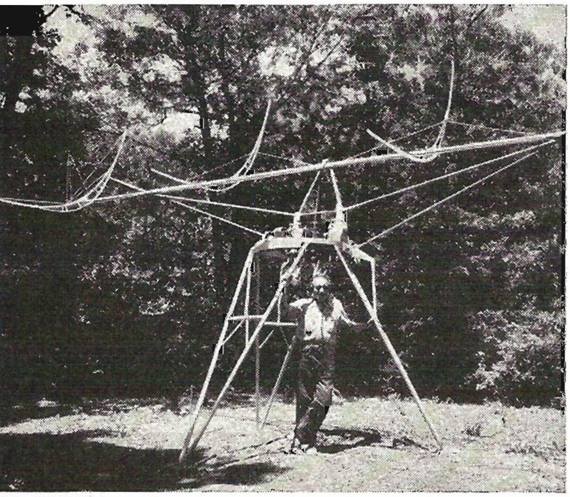




from the visible disc; linearly polarized radiation at frequencies between 30 and 3000 mc.; and very intense bursts of radiation between 5 and 30 mc. The microwave emission originates in an invisible halo—a Jovian Van Allen belt, so to speak—extending over a much wider area than the visible planet. Recent investigation of the Jovian bursts indicates that they occur only when a particular side of the planet is facing the earth and that they originate from an area about one-tenth the size of the planet.

Mercury was added to the roster of radio sources in 1960 when signals were first picked up from it at 1000 mc. Most signals originating from this planet occur above 5000 mc. Of the planets beyond Jupiter, Saturn is presently the only known "broadcasting station"; signals have been detected from this planet at frequencies around 100 mc. and 1000 mc. Undoubtedly, the other planets will in time join this fast-growing "broadcaster's club."

Types of Telescopes. The radio telescope is not as complex as you might at first imagine; in fact, it functions a lot like your small pocket radio. Basically, the radio telescope consists of an antenna, a receiver, and some sort of recording system. The antenna collects and focuses the radio waves much in the same manner as the optical telescope focuses light waves. The focused waves are amplified and detected through a sensitive receiver and then recorded by a recorder or computer. Receivers used in radio astronomy are usually specially-designed types and feature extremely low noise circuits such as the parametric amplifier and maser. Computers are also being integrated into radio telescope setups. Most amateur setups, however, use a superheterodyne-type receiver, an explanation of which can be found in any radio textbook.



An example of what the amateur can do. This antenna was built by Zvi Gazari, a member of the New York Astronomers Association, using surplus parts.

When you consider that radio astronomers detect almost inconceivably faint signals against galactic background noise many times greater than the "brightest" radio source, the need for massive-sized antennas and super-sensitive receivers is readily apparent. Some radio telescopes use a single antenna, others employ many. They may be fully steerable, or fixed. Fully steerable units can be steered in any two coordinates to any point in the sky; partially steerable units can be turned in one direction, usually declination; and fixed antennas can be steered by electrical means.

The most popular design now in use is the fully steerable paraboloid or "dish," a schematic of which is shown on page 41. The world's largest fully steerable dish is the 250′-diameter Jodrell Bank installation in Manchester, England; and the world's biggest partially steerable telescope is the 300′-diameter dish at the National Radio Astronomy Observatory in Green Bank, West Virginia. Other big dish antennas include the 210′-diameter telescope of the Australian National Radio Observatory near Sydney, the new 150′-diameter telescope at Stanford University, California, and the 84′-diameter telescope of the Navy Research Laboratory in Maryland. The record holder for a non-movable radio telescope is the 1000′-diameter spherical reflector at Arecibo, Puerto Rico; nestled in a 450′-deep crater, this colossus functions as a radar telescope as well as a radio telescope.

But the "dish" is by no means the only single aperture-type antenna used by radio astronomers; indeed, there are about as many varieties in use as there are radio telescopes. At Ohio State University, for example, radio astronomers use a tiltable reflector type anten-

(*Continued on page* 89)

RADIO ASTRONOMY

(*Continued from page 44*)

na, whose physical aperture is equivalent to a 152′-diameter dish. Another large radio telescope is the 600′ parabolic cylinder, spread out on an area bigger than four football fields, at the University of Illinois.

In an effort to increase the resolution of the radio telescope, scientists have turned to using multiple-aperture devices instead of building larger and larger single-aperture ones. The resolving power of a radio telescope can be defined as the minimum separation between two radio sources at which the radio telescope can still distinguish that two sources are present.

One such multiple-aperture device now widely in use is the interferometer, the operation of which can be understood by referring to the illustration on page 41. Basically, the interferometer converts the broad antenna beam of a single-aperture device into a large number of fan-shaped beams. Thus it's able to pinpoint many faint sources in small areas of the sky. With the largest dish antennas, the minimum angle of resolution is greater than 1/10°; but with the interferometer, resolutions on the order of 30 seconds of arc or less are common.

Many observatories, notably the Radio-physics Laboratory in Australia, and the California Institute of Technology's Owens Valley Observatory, use variable-spacing interferometers. By varying the distance between the two antennas, varied interference patterns are obtained from which radio astronomers can deduce the positions, sizes, and shapes of very distant sources.

Another widely used variation of the interferometer is the Mills cross or cross-type interferometer. Consisting of an array of antennas arranged in the shape of a cross, it's actually a combination of two interferometers. The great length of these arms of electrically linked antennas results in a very accurate pinpointing of radio sources without the excessive cost of a parabolic dish with a diameter equal to its length. The world's largest Mills cross installation is nearing completion in Australia; it has two mile-long rows of antennas. Other cross-type interferometers can be found at Stanford University, California, Oka Radio Astronomical Station, Moscow, and University of Bologna, Italy.

Another method of achieving high resolution is through the use of an array of half-wave dipoles connected in phase and located above a reflecting screen. One installation, at the U.S. National Bureau of Standards Observatory near Lima, Peru, uses an array of 9000 half-wave dipoles. And, as for future radio telescopes, radio astronomers are talking about telescopes with pinpoint resolution, as well as orbiting and lunar-based units.

Amateurs and The Stars. Each year finds more and more hobbyists joining the ranks of amateur radio astronomers, as radio astronomy is one field where the amateur can really dig in and do some responsible research. Some of these people build their own radio telescopes and work alone out of backyard or rooftop observatories, but the majority belong to amateur astronomy groups.

Actually, you need very little equipment to get started. Some radio sources, notably the sun and planet Jupiter, can be picked up with a standard communications receiver and simple directional antenna. (See August, 1964, POPULAR ELECTRONICS.) You can even substitute an inexpensive voltmeter for a pen recorder. But to get any real degree of resolution, you need a big antenna and more sophisticated instruments, and that usually means joining a club where such units are available.

One amateur reported making a simple high frequency radio telescope using little more than a beach umbrella, a modified UHF converter, and a standard communications receiver. He converted the umbrella to a dish antenna by spraying the inside of it with aluminum paint and then finding the focal point by moving up the umbrella handle with a flashlight. When the area inside the umbrella lit up, he had a pretty good idea where the focal point was. Since this particular amateur was interested in picking up 21-cm. hydrogen "broadcasts," he modified the UHF converter so it would tune as high as 1400 mc. instead of the normal 890 mc., and by using it as a "front end," he was able to employ a communications receiver tuned to 20 mc. There are also many types of surplus equipment, particularly high frequency receivers, which can be adapted for the purpose.

But before you start hoisting a massive dish antenna up to the roof of your house or go about filling up your backyard with dipoles, why not read up on the subject? Many good books are available from your local library or bookshop, some of which are slanted toward the amateur telescope builder. For example: *Radio Astronomy* by J. H. Piddington (Harper & Brothers—now out of print but available at libraries); *Radio Exploration of the Planetary System* by Alex G. Smith and Thomas D. Carr (D. Van Nostrand Co., 24 W. 40th St., New York 18, N.Y., $1.50); *Radio Astronomy And How to Build Your Own Telescope* by John Heywood (Arco Books, 219 Park Ave. South, New York, N.Y., $2.50 cloth, 95 cents paperback); and *Radio Astronomy For Amateurs* by Frank W. Hyde (W. W. Norton & Co., 55 Fifth Ave., New York, N.Y., $5.00).

As interest in amateur radio astronomy is world-wide, so are the amateur societies serving these people. For instance, in England, where radio astronomy is very popular, the British Astronomical Association is a highly respected organization and its members sometimes work with radio astronomers from Cambridge and Jodrell Bank on various experiments. In the United States, the Astronomical League, the parent organization to some 170 clubs, can guide you in selecting a nearby astronomy club. For more information, write to the Executive Secretary, Astronomical League, 4 Klopfer St., Millvale, Pittsburgh, Pa. Westerners and Hawaiian residents can also write to the Western Amateur Astronomers, 4636 Vineta St., La Canada, Calif.

Many of these local clubs have active radio astronomy programs. In the New York City area, for example, the Amateur Astronomers Association, which meets regularly at the Hayden Planetarium, operates a radio telescope in Rocky Point, Long Island; for information on joining this club, write to Amateur Astronomers Association, 212 W. 79th St., New York, N. Y. The Brooklyn Children's Museum, Brooklyn Ave. and Park Place, Brooklyn, N. Y., also has a radio astronomy program.

Where Do We Go From Here? As mentioned earlier, radio astronomy has already told us much about the universe. In less than 20 years, it has enlarged our knowledge not only by discovering radio sources millions of light years away, but also by investigating heavenly bodies closer to us. But even more important, it's providing answers to the origin and perhaps evolution of the universe and the laws inherent in its existence. The farther out we are able to "peer," the farther back in time we go. In this way, scientists are able to analyze age-old signals to determine if physical laws are changing.

Where we go from here depends on man's ingenuity. Since we are discovering new things about the universe every day, the simple radio telescope and its applications may pave the way to even greater feats, perhaps lying just around the corner. And perhaps there will be other Janskys, dedicated men that take time out to analyze what's right in front of their eyes. —30—

TOTEM POLES FOR STEREO

(*Continued from page* 52)

The woofer enclosure is somewhat unorthodox, but very easy to build, particularly if you plan to cover it with a plastic veneer. First cut out all the parts, and before joining the major components, glue and screw the cleats to their proper places on the sides; this will eliminate the need to struggle with them later inside the cabinet. Attach the cross cleats to the rear of the top and bottom pieces, and you are ready to glue and screw together the top, bottom, and sides. Next, make the speaker cutouts in the proper locations in the front, then glue and screw the duct panels to each end of the front panel. Slip the front panel into the enclosure and secure it in place. If you are covering the sides of the en-