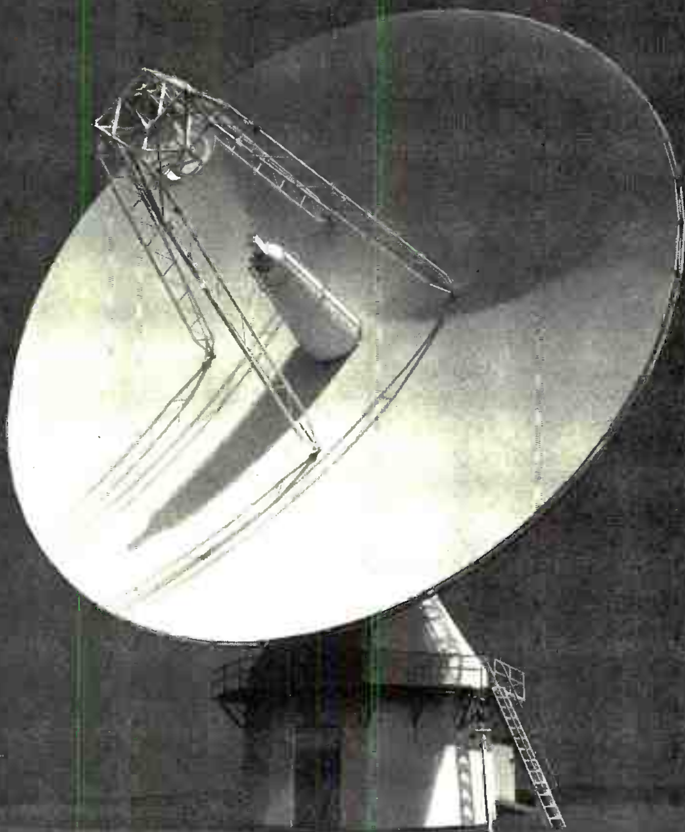
JANUARY, 1967
VOL. 16, NO. 1

The Lenkurt DEMODULATOR

GROUND STATIONS for Satellite Communications



Necessarily, most of a satellite communications system never leaves the ground. Highly directional antennas and elaborate electronics equipment must be stationed around the world to interconnect the orbiting microwave relay with its terrestrial users.

The techniques of communication through satellites and point-to-point microwave radio systems share conceptual similarities: both receive and transmit the same signals at the same frequencies through directional antennas. Differences are in the areas of power, bandwidth, and access to the system.

Point-to-point microwave transmitters span 30-mile distances with 1 to 5 watts, using dish antennas about 6 feet in diameter. Satellite ground stations must work with a repeater 22,300 miles distant, with 10-kilowatt transmitters driving 85-foot antennas. Moreover, the large antenna must be steerable and have the ability to accurately track a satellite in orbit.

At the same time, the satellite must offer access to many ground station "end terminals" — perhaps dozens of countries wanting to relay messages through the same repeater at the same time.

Bandwidths up to 500 MHz place additional demands on the earth station, which must "scoop in" meager satellite signals while maintaining relatively low noise figures. Large antennas, coupled with super-quiet receivers meet the requirements — but not without a great deal of engineering sophistication.

The commercial satellite system is being established through the International Telecommunications Satellite Consortium (Intelsat), with America's Communications Satellite Corporation (Comsat) as manager. Intelsat is providing the satellite relays for its 54 member nations, plus ground control equipment to keep the satellites properly positioned. The individual countries are responsible for establishing and operating their own ground stations — and will coordinate traffic and and tariffs with local carriers.

Since the summer of 1965, earth stations in Europe and North America have been gateways for international communications through the Early Bird satellite. The launching of improved satellites this year will open more channels across the Atlantic and establish service in the Pacific — spanning nearly two-thirds of the earth. For this service to be useful, many new ground stations must be built.

Locations

In the United States, three ground stations are now in operation for use with the new Intelsat 2 satellites. The

Figure 1. Brewster Flat ground station, with folded-horn and Cassagrain antenna (right, in distance). Microwave antennas are visible above building.

station at Andover, Maine, was built to work with Telstar in 1962, and is now a part of the Comsat system. Two new stations serving the Pacific were recently activated at Brewster Flat, Wash., and Paumalu, Hawaii. Comsat plans other stations at Moorefield, W. Va., and in the Caribbean. A station at Mill Village, Nova Scotia, will connect Canada to the global system.

In Europe, major stations are being operated in England, France, Germany and Italy. New stations are being built on Ascension Island by the United Kingdom; at Madrid and on the Grand Canary Island by Spain; and in Australia. Japan is joining the Pacific system with a station at Ibaraki.

Many other sites are being considered: Hong Kong, Bahrain on the Persian Gulf, Thailand, the Philippines, a number of countries in Latin America, the African Continent, and another location in Australia.

Earth stations must avoid all sources of electromagnetic noise — natural or man-made — if faint satellite signals are to be received satisfactorily. Geographic location, frequency allocations, and antenna design all must be considered if noise is to be reduced. Ideally, ground stations are situated in "radio quiet" locations, distant from sources of interference, yet close to power and telephone network interconnect.

Frequency Choice

The choice of frequencies to be used has a great influence on communications satellite technology. An antenna pointed skyward will "see" two types of noise: that from galactic sources, and that from the atmosphere itself. Galactic noise is relatively high at frequencies under 400 MHz, but falls off rapidly at the higher frequencies; galactic noise is negligible above 1 GHz. On the other hand, atmospheric noise increases above 8 GHz, and is considerable above 10 GHz. Logically, the spectrum between 1 and 10 GHz is considered most favorable for satellite communications.

Operating frequencies now in use were adopted at the 1963 Extraordinary Administrative Radio Conference in Geneva. Uplinks (ground to satellite) for commercial satellite systems are in the 6-GHz frequency range, while returning downlinks are in the 4-GHz

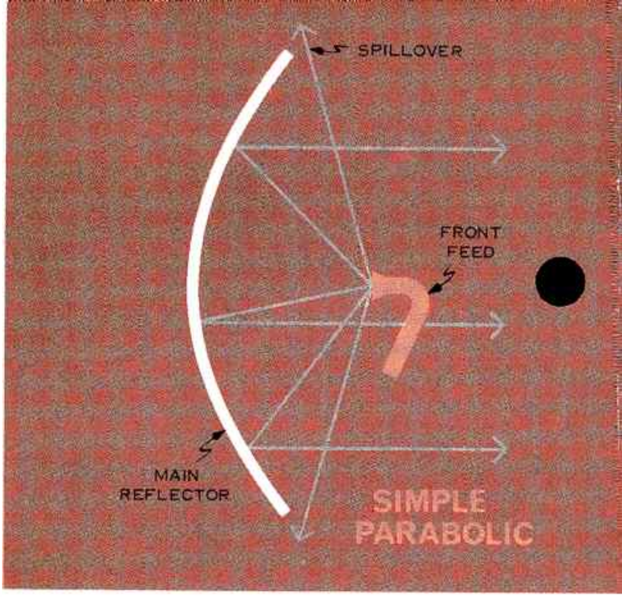


Figure 2. Three versions of the parabolic antenna, showing placement of rf feed and path of reflected energy. The Cassagrain is most practical type for satellite communications.

band. Other bands are used for special purposes, including military communications.

Since many of the satellite allocations are shared with other services, restrictions have been placed on the maximum flux density allowable at the earth's surface. While there are a number of variables, such as angle of arrival and method of modulation, the basic recommendation is for a maximum density of -130 dBw/m^2 in any 4-kHz bandwidth. This restriction limits the power a satellite may radiate, and likewise places greater emphasis on the design of the ground stations that must receive these signals. In many cases, the ground station will be joined to telephone networks by point-to-point microwave radio using the same 4 and 6 GHz bands.

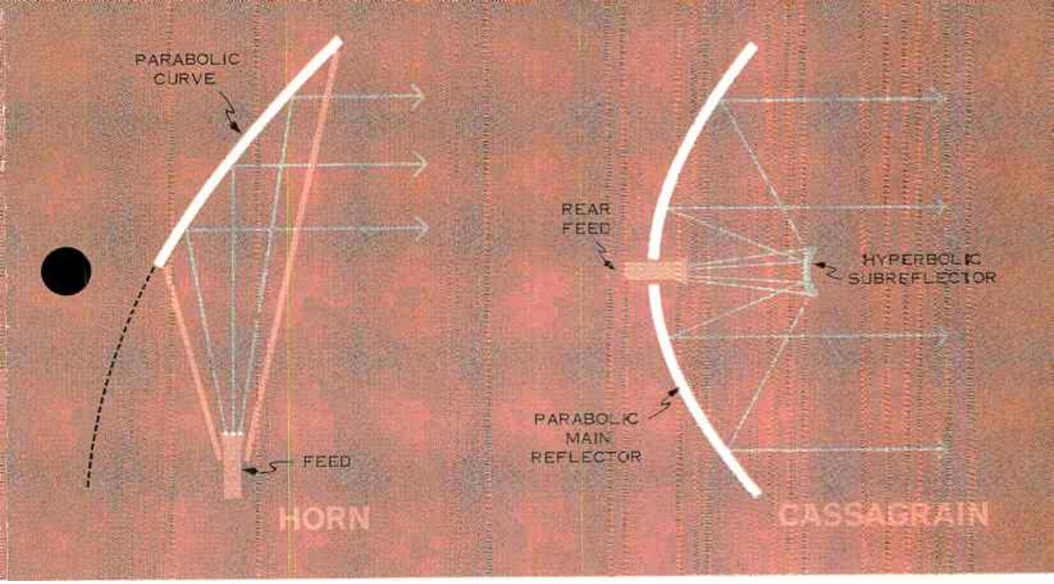
Antenna Gain

Probably the most critical single component in a ground station — and the most costly — is the antenna. It must concentrate transmitter power toward the satellite, and receive communications and tracking signals from the satellite. The desirability of a particular antenna design is directly proportional to the ratio of antenna gain to receiving system noise. Gain is primarily dependent on the physical size of the antenna, and may be defined as the capability of the antenna to concentrate *transmitted* energy in the desired direction. Similarly, gain represents the *reception* of energy from a desired direction and the rejection of energy from other directions.

It is obvious that an effective ground station must have as narrow a beam as possible. While transmitting, the antenna must concentrate most of the radiated power in the main beam, known as the major lobe. Any energy in side lobes is wasted. Conversely, in a receiving antenna the side lobes represent sources of extraneous noise.

Noise Temperature

Noise in antenna-receiver systems is commonly expressed in degrees Kelvin. Since all objects radiate energy — the higher the temperature of the object, the more energy radiated — *noise temperature* is an appropriate unit of measure-



ment for receiving systems. For instance, a highly directional antenna pointed at the sun (surface temperature about 6000°K) will receive a noise power of 8.28×10^{-14} watts, or -101 dBm.

The concept of noise temperature is easily extended to other noise sources. Any device which produces random noise of 4.0×10^{-21} watt (-174 dBm) per cycle of bandwidth, may be said to have a noise temperature of 290°K — even though that may not be its physical temperature. In other words, the noise temperature of a device is the temperature at which a thermal noise source would have to be operated to produce the same noise power. Expressed as temperatures, noise units from antenna and receiver are conveniently added to arrive at a total system noise value.

Antenna Design

Three variations of the basic parabolic reflector can be considered for satellite communications ground stations — with noise performance the constant criterion.

The basic parabolic antenna (Figure 2), like those used in point-to-point microwave transmission, is a highly directional device. However, the center feed at the focal point of the antenna cannot be precisely controlled to illuminate only the reflector. A certain amount of "spillover" occurs in even the best system, adding undesirable lobes at the back and sides of the antenna. With the antenna reflector looking skyward, the feed is pointed back at the relatively noisy ground (approximately 290°K). Spillover from the simple parabolic adds to the antenna's noise temperature. Also, it is mechanically inconvenient to mount needed preamplifiers at the feed of the simple parabolic.

In an attempt to reduce minor lobes, the horn reflector antenna was developed. The antenna is basically a section of a parabola, with sides extended from the feed to the edges of the reflector. The horn is a highly efficient, low-noise antenna, but is large and costly. The first U.S. commercial satellite ground station at Andover uses a horn reflector weighing 380 tons.

The popular choice is the Cassagrain antenna. The double-reflector system incorporates a parabola main reflector, and a hyperbola subreflector. The feed is at the rear of the main reflector and looks, with the antenna, at the sky (noise temperature typically less than 30°K). In operation, rf energy from the feed strikes the subreflector and is bounced back to illuminate the main reflector as if it had come from the focal point of the parabolic.

The Cassagrain antenna (named for William Cassagrain who developed the subreflector method of improving optical telescopes) is superior to the conventional parabolic in a number of ways. The antenna has low spillover, shorter transmission lines, greater mechanical stability in the feed system, and more flexibility in design. Careful engineering eliminates the otherwise serious disadvantage of placing elements that could block radiation in front of the antenna.

The typical commercial ground station uses an 85-foot Cassagrain. Illustrated on the cover is the antenna recently installed by Sylvania Electric Products, Inc. at two Comsat stations.

Variations

Other variations exist, especially in mobile and transportable antennas. A 42-foot transportable folded-horn antenna is being used at some commercial ground stations while the more complex Cassagrains are readied for service.

The smaller the antenna, however, the higher the noise temperature of the system. Likewise, the lower the signal-to-noise ratio, the less bandwidth available for communications. The 42-foot folded horn is designed to provide a limited number of channels for telephone, telegraph, and high-speed data, but the 85-foot Cassagrain must be used for television transmission.

Willing to sacrifice bandwidth for mobility, the military is developing a number of smaller units for field and shipboard use. The smallest antenna system may service only one voice channel, but allow reliable long-range communications to be established at virtually any remote location in hours.

Pointing Accuracy

Large reflectors characteristically have high gain and narrow beamwidths; sophisticated control is required to keep these antennas properly aimed at the small point in the sky.

The accuracy imposed on earth stations is illustrated at Brewster Flat and Paumalu. The movable portion of the antennas at these new stations weighs more than 135 tons, but must be able to rotate 360 degrees in 120 seconds, and track satellites to within 1/500th of a degree!

It should be noted, however, that when commercial satellite systems are fully removed from the experimental stage and configurations are firmly established, little antenna adjustment should be required.

With any narrow-beam antenna, the transmitted signal must be pointed in a precisely known direction. Mechanical vs. electrical alignment is accomplished in much the same way an expert marksman corrects the sights on his rifle — by carefully aiming, firing a shot, and noting where it hits.

A 6-foot "boresight" antenna is the target for the ground station antenna. The boresight facility simulates the satellite's performance by translating a received signal to a different frequency and returning it to the ground station. By pointing the large antenna at the target and plotting returned signals, engineers can calibrate accurately the true direction of the narrow radiated beam.

Amplifiers

In operation, usable signals from the communications satellite are possible because of high-gain, low-noise antennas matched with ultralow-noise preamplifiers. The preamplifier, which might be a maser, parametric amplifier, or other similar device, is placed as near as possible to the antenna feed. A parametric amplifier operating as the initial microwave amplifier, may have a noise temperature of only 15°K. The entire receiving system, including antenna, could be rated at less than 50°K. Compared to the 1200°K temperature of a very good receiver only a few years ago, it is easy to recognize the great technological advances necessary for a practical satellite communications system.

Ground stations must transmit powerful signals to the satellite. Comsat stations use either traveling wave tube or klystron power amplifiers to produce 5 to 10 kilowatts of rf energy. The TWT is generally used for its greater bandwidth, while the more powerful klystron serves tunable narrow-band applications.

Telephone Interface

The national telephone network is connected to remotely located ground stations by point-to-point microwave radio relay. At Brewster Flat, for example, three separate microwave channels in the 11-GHz range — one for voice, one for television, and a protection channel — carry communications to and from the site. A parallel microwave system in the 2-GHz band carries order wire and control signals.

Multiplexed voice channels are interconnected to ground station equipment at the standard group frequency level (60-108 kHz). Comsat equipment further processes these voice signals, along with wideband television signals, to be fed to separate radio transmitters. The outputs of these transmitters, in the 5925 to 6425-MHz band, are combined through the power amplifier before they are supplied to the ground station antenna. Received signals are handled in essentially the reverse manner.

Signaling

Increasing global communication through satellites focuses attention on the technical necessity for agreement between many countries. One of the most difficult technical problems in international telecommunications is signaling. Successful interface with large numbers of unique national switching systems must be achieved.

Members of the International Telegraph and Telephone Consultative Committee (CCITT) have agreed on a system to send line or supervisory signals at two in-band frequencies in a link-by-link arrangement. The register or numerical signaling, also link-by-link, uses two out of six in-band frequencies.

A proposed revision, if adopted, will mark the first time a completely new equipment design has been undertaken by international committee action. The new system would transmit signaling over a common channel separated from voice circuits.

Discussion continues on future methods of handling carrier group and supergroup pilots, necessary for level regulation. CCITT recommendations place the pilots near the middle of the group frequency bands, but the Bell System has moved them to the edge to allow for wideband data service. The need for coordination between such varying systems has been accentuated by satellite communications.

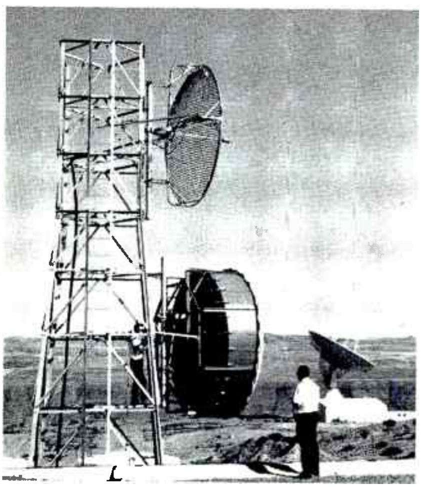
Lenkurt Electric Co., Inc.
San Carlos, California

Bulk Rate
U.S. Postage
Paid
San Carlos, Calif.
Permit No. 37

MR. E. A. GARCIA
CHIEF OPERATOR
% MILWAUKEE ROAD DEPOT
SAVANNA, ILL. 61074
R-124948 6B

RETURN REQUESTED

75/76 Microwave for Comsat



The Pacific portion of the Comsat global communications system is being linked to major telephone switching networks with Lenkurt microwave radio.

Ground stations at Brewster Flat, Wash., and Paumalu, Hawaii, are connected to telephone facilities up to 90 miles away with high-density type 75 and 76 microwave radio systems. At Brewster Flat a parallel type 71F radio route provides order wire and control signal transmission.

Other Lenkurt equipment at the ground stations includes 46A and 34A multiplex, 936A alarm, 53C order wire, and 23A telegraph and data transmission systems. For more information on Lenkurt products, write Dept. B720.

LENKURT ELECTRIC San Carlos, California, U.S.A.
SUBSIDIARY OF
GENERAL TELEPHONE & ELECTRONICS GT&E

Lenkurt Offices

San Carlos
Atlanta
Dallas
New York City
Washington, D. C.
Chicago

THE LENKURT DEMODULATOR is a monthly periodical circulated to technicians, engineers, and managers employed by companies or government agencies who *use and operate* communications systems, and to educational institutions. Job title, company affiliation, and nature of business must be indicated on subscription requests. Each issue features an instructive article on a subject dealing with the science of telecommunications. Permission to reprint articles may be obtained by writing THE EDITOR.

LITHO IN USA