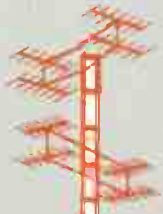
MARCH, 1966
VOL. 15, NO. 3

the Lenkurt Demodulator

Community Antenna TV



Master antenna systems are serving an increasing number of American communities, providing television reception where before there was none. By extending the viewing area of both commercial and educational television stations, these small networks of coaxial cable and microwave radio have collectively established a new and sizeable industry.

This article discusses the operation of these systems, and related items of interest in the field of educational television.

The establishment of the television industry in the United States brought with it new concepts of entertainment, news, and education, adding immediacy and depth. At the moment there are over 700 television stations in this country (Figure 2), and over 100 construction permits have been granted by the Federal Communications Commission to establish new stations.

Simultaneously with the growth of television — and almost unnoticed during its early years — cable TV systems appeared, stretching TV coverage into otherwise poor signal areas. CATV, for Community Antenna Television, is now a sizeable industry of its own serving close to two million U.S. homes. Similar systems also are developing in other countries, including Canada, Mexico and Great Britain.

A Beginning

CATV is essentially a master antenna service for receiving television signals and distributing them to home receivers. When the first television stations went on the air in the late 1940's, it was found that signals in outlying areas were not always powerful enough for satisfactory reception. Potential TV viewers were either too far from the broadcasting station, or were in a shadow area behind a nearby mountain or other obstruction. Even the construction of costly roof-top antennas was not always successful.

The first meager steps toward the new CATV industry were made by local citizens joining forces to construct master antennas on nearby hilltops. The signal was carried down the hill by standard TV lead-in wire strung from tree top to fence post to pole, and interrupted regularly with unsophisticated booster amplifiers. The results were not always ideal. The first commercial installations, with better antennas and coaxial cable came in 1950. Soon equipment manufacturers were entering the field with specially designed CATV receivers, cable amplifiers and other components. When greater distances separated the TV station from the community, microwave radio replaced long

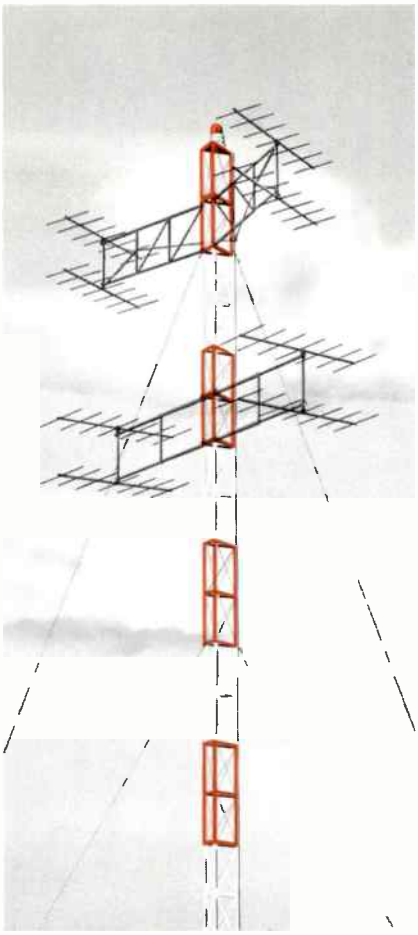


Figure 1. High gain Yagi antennas, one for each television station, receive off-the-air signals to be relayed through CATV system.

coaxial cables as the most economical method of insuring good TV reception.

CATV Today

Today, approximately 1600 CATV systems are in operation, another thousand have the go-ahead from local franchising agencies, and over two thousand are pending approval. However, it should be understood that not all of these will be built immediately or even in the near future. Some predict about 100 new systems for 1966, increasing to a total of about 2600 by the end of 1970. Only one state does not have at least one operating system, but even there applications for service have been filed. Some larger states have hundreds of independent systems.

	VHF	UHF	TOTAL
COMMERCIAL	486	101	587
EDUCATIONAL	66	49	115
TOTAL	552	150	702

Figure 2. Numerical breakdown of TV stations now on the air.

CATV systems vary greatly in size and capability, from small operations carrying as few as two channels, to advanced and more elaborately equipped facilities bringing as many as 12 TV channels and a number of FM radio signals to the subscriber. The average subscriber receives five stations, while less than one percent get 10 or more channels. Four percent receive only two channels. Soon equipment advances may make it possible for a CATV system to carry 20 or more channels. Small operations may have only a hundred or so subscribers, while the largest in the United States serves nearly 20,000.

In its early years, CATV served the small population centers scattered some distance from television stations. More recently, however, CATV has been brought to the doorsteps and even into the parlors of major cities like New York, Los Angeles, and San Francisco. Tall buildings, natural obstructions, airplanes, and other such factors will degrade television signals from even nearby stations. The advent of color television also has increased the need for high-grade signals for satisfactory picture reproduction.

In addition to providing improved TV reception, CATV frequently includes bonus services placed on otherwise unused channels. An example is weather information from a camera continuously scanning temperature, wind, and other gauges. Another service allows home viewers to read the latest news as it is typed on news-wire machines.

At least one operator has gone further than that, setting up television-like studios to provide news, discussions, speeches, children's programs, and even live sports events. Equipment includes mobile units, video tape recorders, and professional studio consoles. Commercial background music also may be supplied by CATV, using already installed cables to carry recorded music to business concerns.

The CATV Signal

The first need of a CATV system — like the home receiver — is a good signal from the broadcast station. In some countries, broadcasters will provide a direct program feed from the station. But American CATV operators pick up television signals "off the air" with specialized receiving equipment. High gain antennas, typically of Yagi design, are

situated on a mountain peak or other advantageous point in the terrain. These antennas are selective, narrow band devices, most efficient at only one frequency or channel. Therefore, a separate antenna is usually installed for each channel to be received. Ideally, TV signals at the antenna site should have a minimum strength of 50 microvolts per meter.

Special receivers detect the TV signals, convert UHF to VHF if necessary, and amplify them to suitable levels for transmission. This portion of the CATV system is known as the "head end" equipment. If the signals are to be fed directly into a cable trunk line, standard VHF television frequencies are used. However, if a local VHF station is carried on the cable, interference will usually result between the direct signal from the transmitter and the signal on the cable. In such cases it is necessary to translate this station's programs to a different channel prior to distribution.

When distant TV stations are to be carried, it is often more practical to use microwave radio links over sometimes as much as hundreds of miles to reach distribution trunk cables. For the head end equipment to feed a microwave system, incoming TV signals first must be demodulated to more usable frequencies. That is, the carrier frequency must be removed, leaving only pure video information in the range from 10 Hz to 4.2 MHz (Figure 3) with the audio on a subcarrier at 4.5 MHz. This is called a *composite signal*, and may be used to directly modulate the microwave radio. It is also possible to separate the video and audio signals at this point and place the sound signal on a higher frequency program channel.

The output of the microwave radio is transmitted by highly directive parabolic antennas to receiving stations 20 or 30 miles away. Then the signal may be retransmitted to another repeater, or fed into more head end equipment for cable distribution.

The Federal Communications Commission regulates all radio frequency allocations, and recently created a new Community Antenna Relay Service (CARS) for exclusive use by all CATV operations. The band is from 12700 to 12950 MHz.

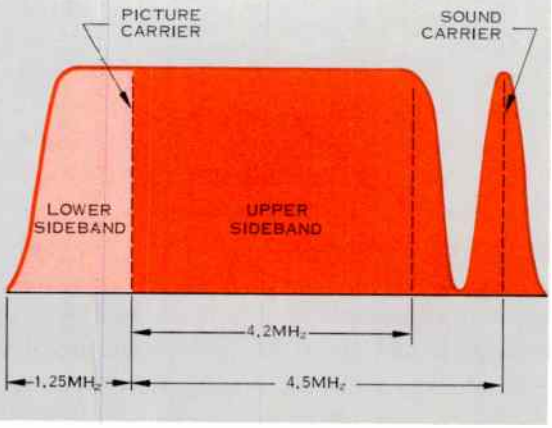


Figure 3. Television spectrum. Upper sideband of video, plus audio carrier make up composite signal.

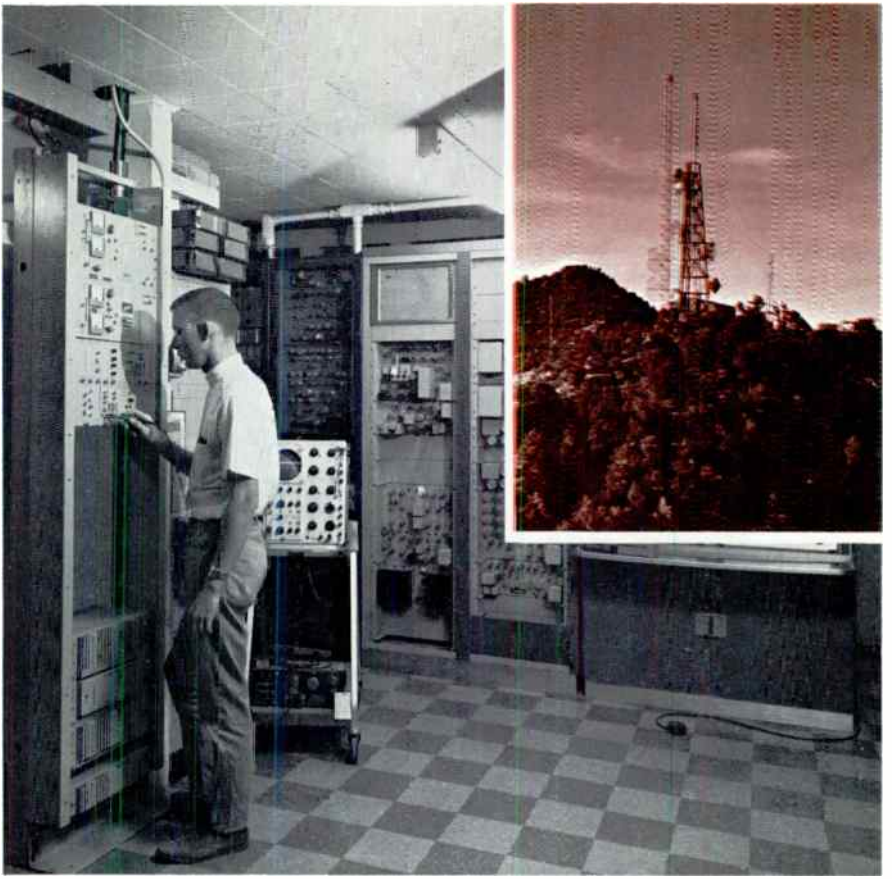


Figure 4. Lenkurt 76TV microwave radio in typical installation. Repeater stations (inset) receive and retransmit signals.

Approximately 25 percent of the CATV systems in the United States use microwave radio, the typical system requiring two or three hops to bring the signal to the cable distribution point.

Picture Distortion

The transmission of television, especially color television, by microwave includes a number of critical problems. Distortion, poor frequency response, and other transmission irregularities all tend to degrade the quality of the final picture image. Of particular importance is the extreme sensitivity of television signals to non-linear phase shift. Ideally, the entire system should be free of non-linear phase shift from almost zero frequency to at least 4.5 MHz (to cover the bandwidth of a video signal). In practice, this is difficult if not impossible to achieve. Components in the

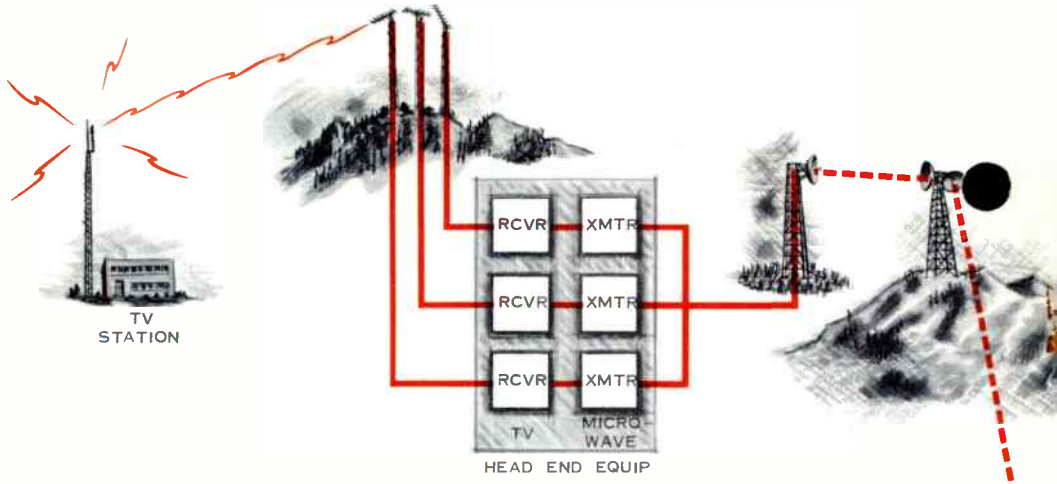


Figure 5. CATV system picks up signals outside the reach of home antennas; may use microwave radio to relay them to cable distribution point. Utility poles carry coaxial cables through residential areas.

system delay some frequencies more than others, distorting the waveform. Although delay distortion of speech or music is not readily detected by the ear, similar distortion of a television signal is very noticeable and grossly affects the quality of reproduction.

Color television is particularly vulnerable to *differential phase* and *differential gain*. The color appearing on the screen is determined by the exact phase relationship between two signals, the color burst and the color subcarrier. An unintentional shift in phase results in a different hue of color. Similarly, change in amplitude of the signal determines the saturation or *richness* of the color. (For additional discussions of these areas see the *Demodulator,* February, 1962; October, 1963; November, 1963; January, 1965).

Delay distortion is directly related to the bandpass characteristics of the entire transmission system, including head end equipment, microwave links, and cable facilities. System design must provide for a very wide bandwidth free from irregularities well beyond the actual frequency limits of the television signal itself. For example, the Lenkurt 76TV microwave system (Figure 4), designed specifically for television transmission, has a frequency response of ± 0.5 dB from 20 Hz to 5.5 MHz.

Subjective testing has shown that phasing errors of 5° or more will be detected by the viewer as a change in hue. Likewise, he will find a 2 dB change in color saturation objectionable. In the 76TV, differential phase is less than 0.5° per terminal, while differential gain is held to 0.2 dB at up to 90 percent of applied picture loading.

Ultimately, the signals must be fed into the cable trunk line for distribution to home TV sets. In a system not

using microwave, this occurs immediately after the signals are received by the master antenna. With microwave, more head end equipment is found at the final radio hop. Here, signals must be brought to proper levels, remodulated to VHF frequencies, combined, and fed into the main trunk lines (Figure 5).

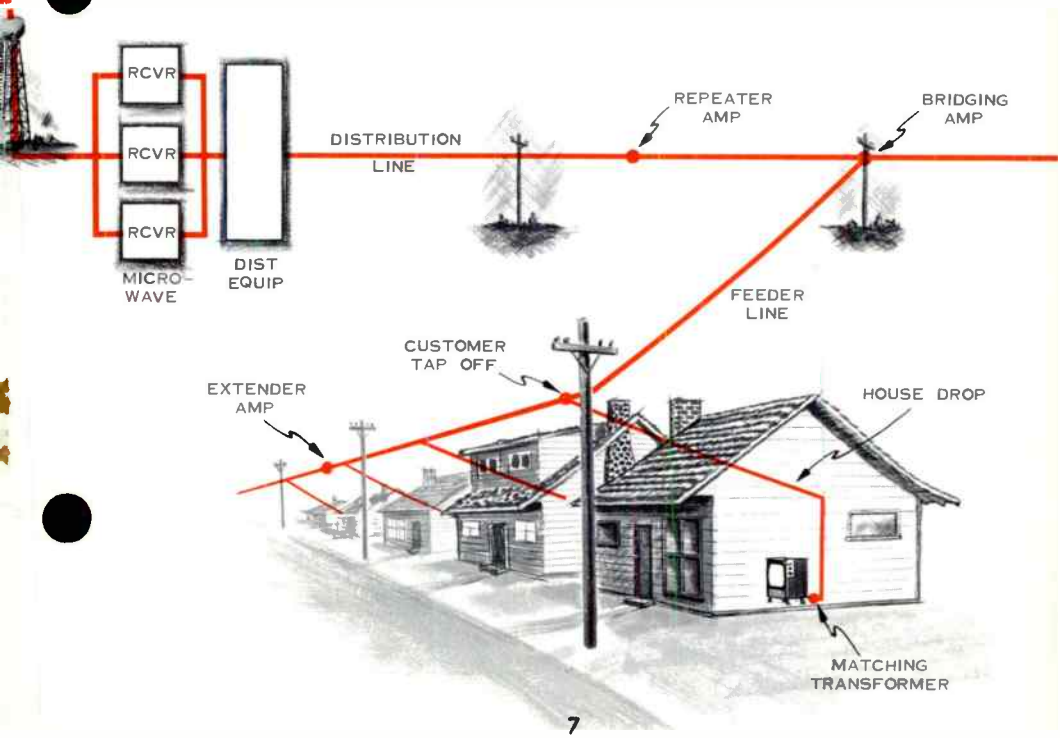
Cable System

The trunk line is the basic carrier of the CATV system and is never tapped to feed individual subscribers. At the intervals along the trunk line are a number of repeater amplifiers (Figure 6) to compensate for signal loss. These are usually less than a mile apart. Bridging amplifiers divert the signals onto feeder, or distribution lines.

Customer "tapoff" units (Figure 7) are placed along the feeder cables. These cause a slight disturbance on the line and therefore a limited number — usually 30 to 40 — are allowed on one line. Extender amplifiers, spaced about every 600 to 700 feet, are used to boost the signal along the feeder line. From the tapoffs come the house drops leading to the subscriber's TV set. However, before a connection can be made, the cable impedance of 75 ohms must be matched to the 300 ohm input impedance of the set through a matching transformer, placed on or near the back of the set.

Troposcatter

CATV operators in other countries have added their own variations to the methods of signal transmission. In Canada, for example, military-developed techniques of troposcatter are being used in some systems spanning rugged terrain. Dependent on the ability of the troposphere to diffuse or scatter a por-



tion of a high frequency signal well beyond the horizon, tropo systems send VHF television skipping over distances from 100 to 500 miles (Figure 8). Stationary tropo antennas may include a tower-supported wire mesh reflector 50 to 60 feet high, almost 300 feet wide, stretching in a parabolic curve around the antenna fixture mounted on the head end building. These antennas are highly directional, and have good ability to reject co-channel and adjacent channel interference.

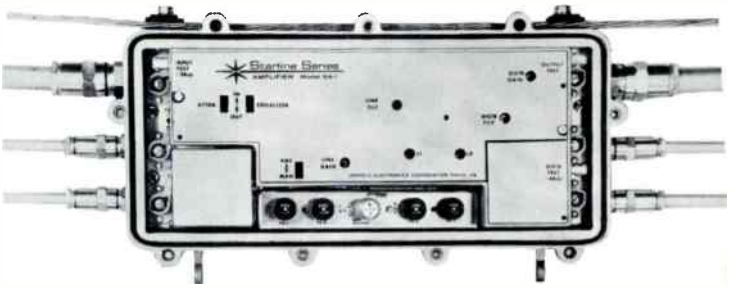


Figure 6. CATV signals pass through trunk-line and extender amplifiers before reaching the home receiver.

British CATV

In Great Britain CATV is called "wired broadcast" or "communal aerial system", and uses two different methods of signal transmission. One system is essentially the same as that used in the United States, relaying signals at standard VHF TV frequencies directly to the receiver. Another popular technique is an outgrowth of the older "wired radio" system. This radio relay system was basically a public address system supplying audio directly to speakers in the home. The television version transmits unmodulated video signals (3-10 MHz) over twisted wire pairs to TV receivers built without the customary r-f front-end amplifiers. Economy is the prime justification for the technique — both the home receivers and the transmission wire are less expensive.

In the British system, head end equipment supplies approximately 40 watts of video power to the trunk lines, which may be up to 6000 yards long. Feeder lines may branch off the trunk lines for distances up to about 2000 yards. It has been found that four video signals with their accompanying audio, and four additional radio channels may be carried on two twisted pair (four wires) in a shielded cable.

Educational TV

Sharing some of the problems, and related in many ways to CATV are the three overlapping areas of educational television (ETV), instructional television (ITV), and closed circuit television (CCTV).

ETV is generally meant to include non-commercial broadcast stations, both VHF and UHF. ITV refers to program content rather than facilities, and relates directly to formal education. CCTV describes the transmission of television by cable or microwave to a predetermined audience, as opposed to

public broadcast. Additionally, our reference here is primarily to the use of CCTV in education.

There are four general types of licensees operating educational television stations: (1) universities, (2) public school systems, (3) statewide ETV commissions, and (4) non-profit "community" corporations. More than half the ETV stations in the country fall into the first two categories, being directly responsible to educational institutions. Likewise, a statewide commission's prime interest is usually with the school systems of the state. And while the community stations may have no direct connection with schools, they usually carry a regular schedule of instructional programs.

The average ETV station broadcasts 5 or 6 days a week, 10 to 11 hours a day. Programs are divided almost equally between classroom instruction and more general programming planned for home viewing by all age groups. Instructional material more likely will be seen during the normal school hours, with more general programs in the early evening, and informative discussions or entertainment features for adult viewing in the late evening.

At this time there are 115 ETV stations on the air, with another 65 under construction or with applications pending. Currently more than half of the ETV stations are on VHF frequencies (channels 2-13), but most reserved allocations for the future are in the UHF band (channels 14-83).

In the School

Closed circuit television is utilized by many schools to make more advantageous use of teachers and instructional material. There are about 800 CCTV installations in this country, split almost equally between elementary and secondary schools, and colleges and universities. These may operate within one school, delivering lectures or demonstrations to other buildings, or between various schools in a district. Within a single school, coaxial cable easily connects the cameras and studio equipment

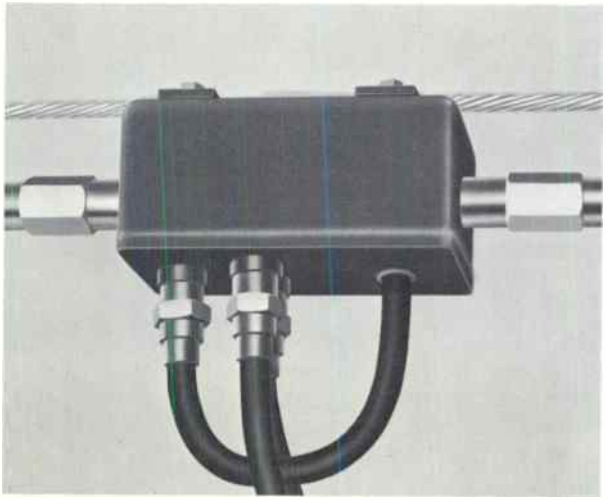


Figure 7. Tapoff units connect house drops to feeder lines, and are designed to prevent interfering signals from reentering cable.

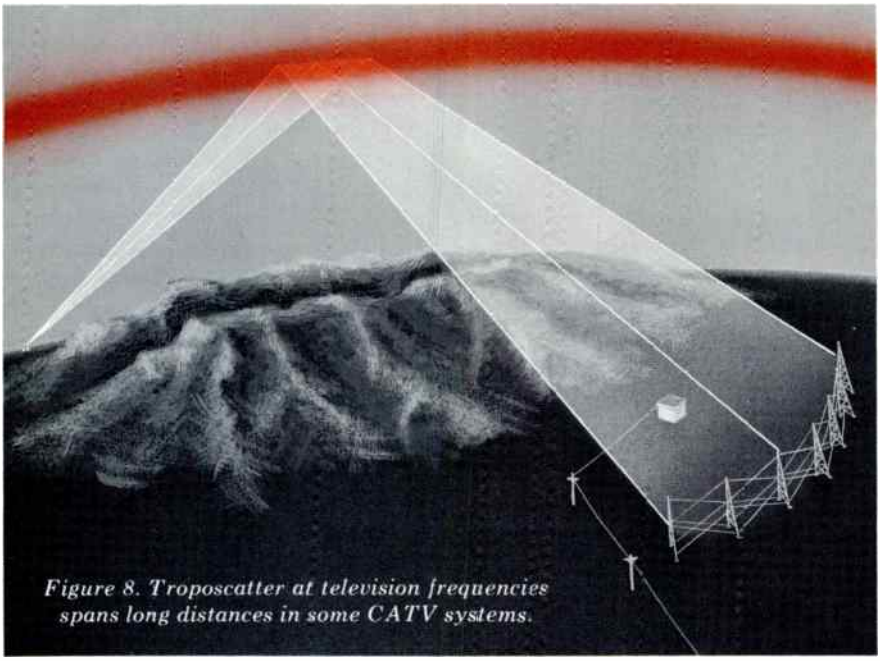


Figure 8. Troposcatter at television frequencies spans long distances in some CATV systems.

to other viewing locations, sometimes with three or four programs on a single cable. Longer runs between separate schools can also be practical, using telephone company cables on a leased basis.

An increasing trend in ITV is the use of microwave radio. The FCC has allocated 31 channels in the 2500 to 2690 MHz band for use by educational institutions. Some districts use these channels as direct links between two schools. Others operate a central transmitter beaming programs in several directions at once, much like a standard broadcast station, to be received off the air at various schools within the district.

ITV systems also operate point-to-point microwave relays on two higher frequency bands. The primary allocation is in the 12200 to 12700 MHz band. However, the FCC will consider applications on a case-by-case basis for the 6575 to 6875 MHz band when the operator can show that it is not technically feasible to use the higher frequency.

Frequently CATV systems will carry ETV programs, thereby greatly extending the range of the station. These may even be piped into the schools, hospitals, or other such facilities in distant towns for little or no charge. In many cases CATV operators also will allow two ETV stations to share programming over a spare microwave channel.

Networks

Many states have already installed widespread microwave networks connecting educational institutions hundreds of miles apart. Similarly, moves have been made to connect large num-

bers of ETV broadcast stations into educational networks. And many CATV systems are beginning to resemble small networks. It is possible that someday a combination of these efforts will bring to this country a "fourth" major television network joining the best educational and cultural programs in all parts of the nation. Moreover, a fifth network, with commercial UHF stations linked from one end of the country to the other, is being considered.

There are also other possibilities for bringing educational and cultural programs to larger audiences. One quite successful experiment has been undertaken by Purdue University, transmitting previously video taped programs from specially equipped airplanes circling 23,000 feet over Indiana. Daily, over a half-million students in six states (a total of 127,000 square miles) receive courses ranging from elementary to college-level subjects.

From the beginning, telephone companies have been involved with CATV systems, allowing cables to be strung on their utility poles. More recently, telephone companies have supplied cable transmission channels for CATV systems and instructional TV operations on a lease or tariff basis. And now many operating companies are expressing interest in becoming CATV operators themselves.

The Future

In the next few years both CATV and educational television undoubtedly will experience many changes. Advancing techniques will allow for greater numbers of channels to be carried over microwave and cable facilities, bringing even more programs into homes and schools across the nation. Satellite technology may add a new dimension with the possibility of broadcasting directly to schools — or even home receivers — anywhere in the nation.

In the United States close to 98 percent of the homes have at least one television set. Three percent of these homes are served by CATV. Educational programming is now available to an estimated 130 million people—another 10 million to be added this year with 14 new ETV stations. In addition, instructional television today reaches two out of three of the nation's 50 million students.

As new networks link one station or relay system to another and new operations spring up, a continually expanding measure of entertainment and education will be easily available to the television public.

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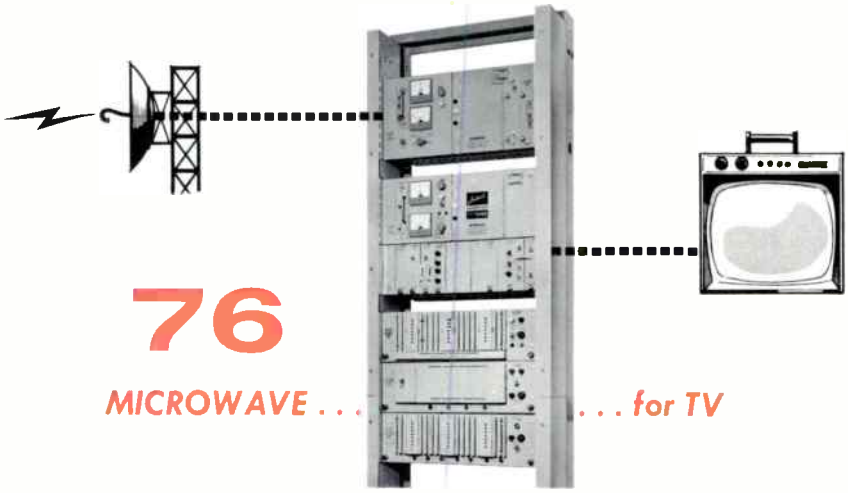

76

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The Lenkurt 76 microwave radio system is ideally suited for television relay—monochrome or color—combining solid state reliability with superior signal handling capability. For CATV, ETV or broadcast studio links. For a few miles or a few hundred. Check the features of the 76 radio against your most demanding needs. Write Lenkurt, Dept. B720 for details.