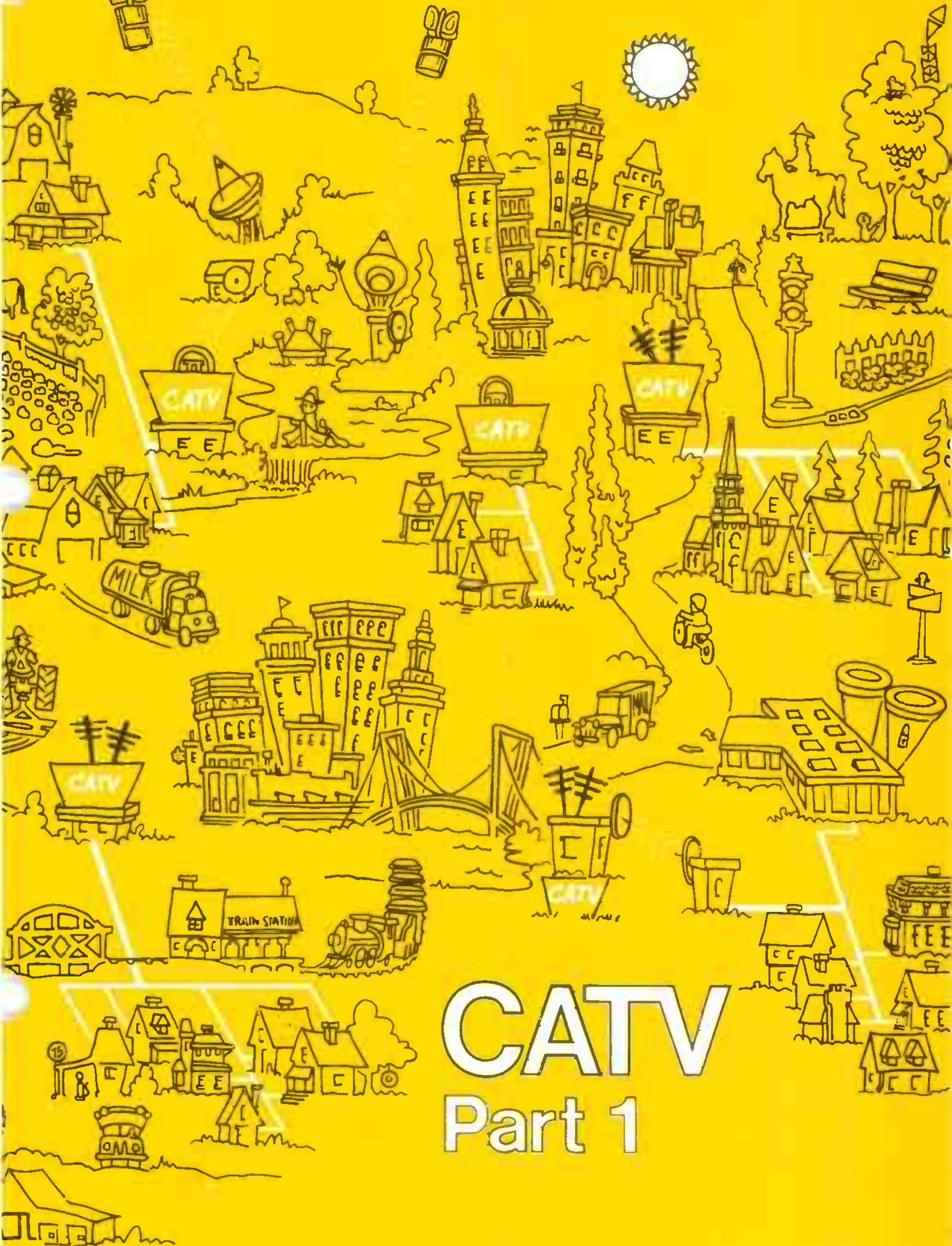
GTE LENKURT

DEMODULATOR

JULY/AUGUST 1979



CATV Part 1

The first commercial cable television, CATV, systems were placed in operation in 1949. These first systems were constructed in areas where distance or natural obstructions prevented the satisfactory reception of direct broadcoasts. In those days, broadcasters encouraged the expansion of cable because it increased their viewing audience and consequently their advertising revenues.

The situation is different today. Highly sophisticated cable systems are operating in large metropolitan areas and successfully competing against direct broadcasting. This first of a two part series describes such a modern cable system. The second part will describe how these systems are designed, installed and maintained. Possible future developments will also be discussed.

Basically a Community Antenna Television (CATV) system is comprised of a head-end station and a coaxial distribution network. As shown in Figure 1, the head-end accepts signals (termed software in the figure) from a variety of sources including satellite earth stations, direct television broadcasts and terrestrial microwave links. Original program and prerecorded material from studio equipment is also accepted.

Head-end station locations are chosen to assure particularly good reception. Mountains, hilltops or the tops of tall buildings are favored. Individual antennas are used to receive each VHF or UHF television broadcast. Broadband antennas are used for local reception and tuned, carefully oriented arrays are used to take signals "off the air" from more distant stations. The antennas are mounted on towers when necessary. Preamplifiers are sometimes used between the antenna output terminals and the transmission line that carries the signals into the station.

Signals from points too distant for reception are transmitted to the head-end over terrestrial microwave relay links and/or domestic satellites. The terrestrial systems are frequently backbone routes with drop and insert facilities at several CATV locations. These routes are frequently owned by "Common Carrier" companies, who provide service to CATV operators on a leased basis. Figure 2 is a photograph of a head-end station.

The availability of low cost, receive only earth stations has reduced the use

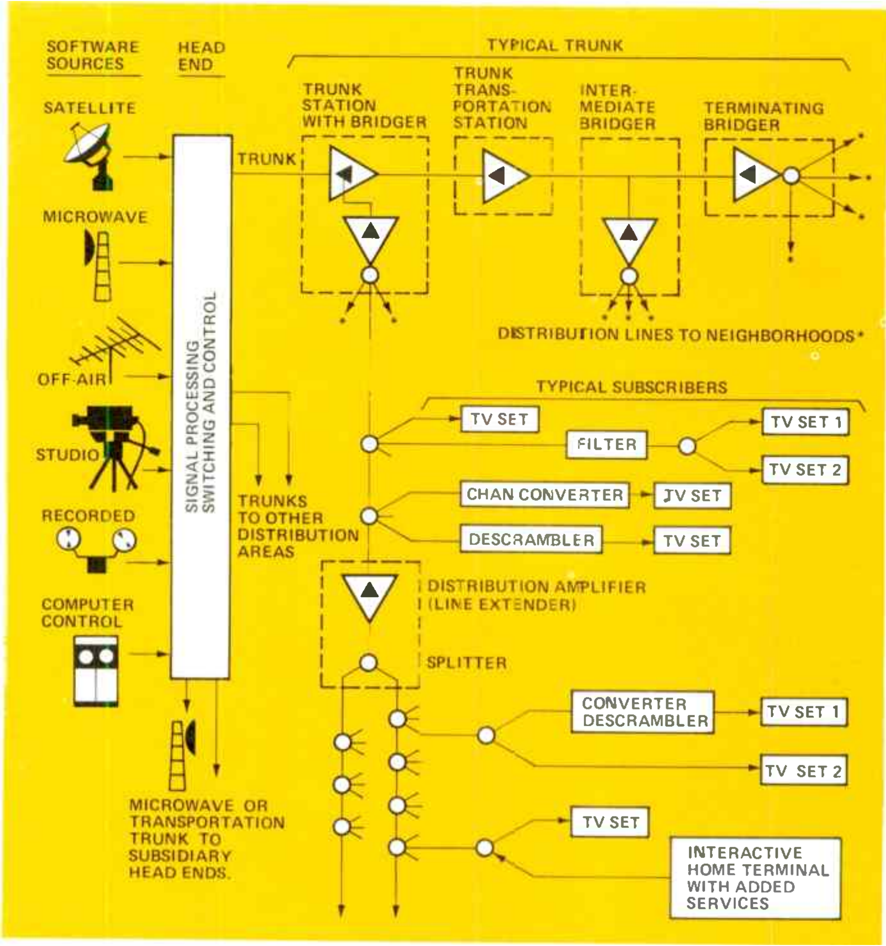
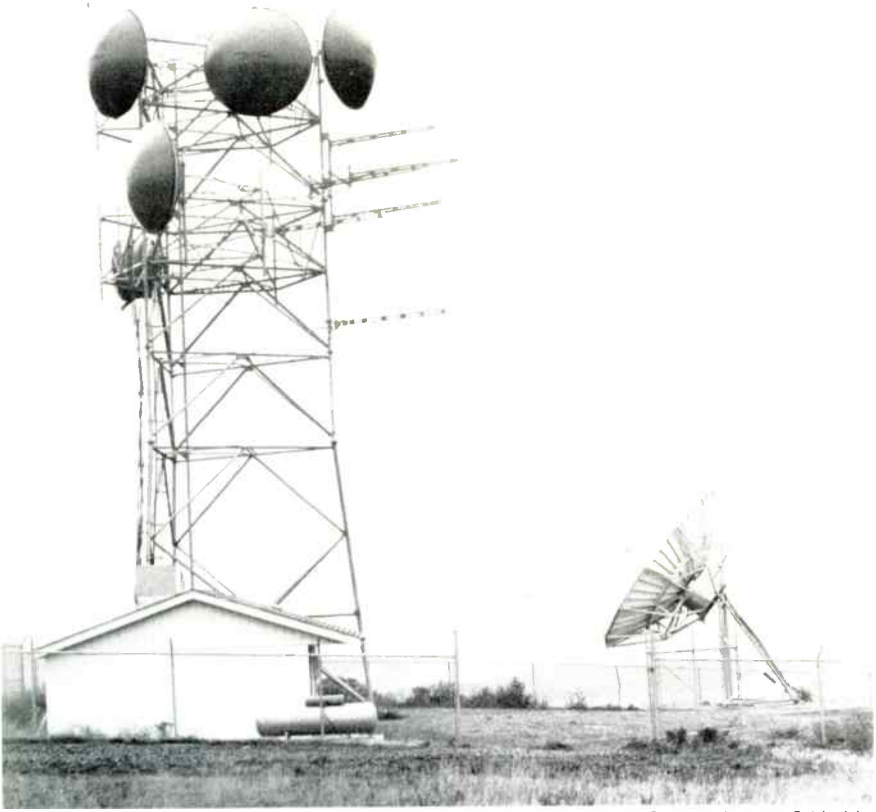


Figure 1. CATV system block diagram.

of backbone systems. Informed estimates are that more than 3,000 earth stations will be serving over 5,000 CATV systems by the mid-1980's.

Some MSO's (multiple systems operators) are rearranging their systems so that signals with distant origins are transmitted via satellite, received at an earth station, transmitted via a microwave link to the main head-end and fanned out to subsidiary head-ends over separate microwave links. These fan-out links are typically 10 to 60 miles in length, in contrast to backbone systems with end-to-end lengths of several hundred miles.

Using microwave radio links to subsidiary head-ends is not a particularly new idea. Amplitude modulated microwave links (AML's) have been used for this purpose for sometime. However, the links to be fanned out will often have several hops. Some operators prefer fm for this application because fm microwave is essentially transparent to cable, whereas AML makes a substantial noise contribution. The equipment that originally formed



Courtesy Viacom Cablevision

Figure 2. Typical head-end station. Receive only earth station is on the right.

backbone routes can possibly be reused in this case.

Head-End

The head-end station provides all the processing equipment necessary to condition the signals for transmission over the coaxial distribution system or AML link. Incoming microwave signals are demodulated down to baseband (In the case of leased backbone routes, this step is usually accomplished by the common carrier). The baseband signals are used to modulate a television channel carrier or an AML link.

Figure 3 is a partial block diagram of a Head-End Station. The head-end equipment includes bandpass and bandstop (trap) filters, processors, converters, modulators and mixers.

The filters are used to pass wanted and to block unwanted signals. They are necessary because even the best tuned antennas will pick up adjacent channel signals. For example; assume a tuned yagi is used to receive channel 3

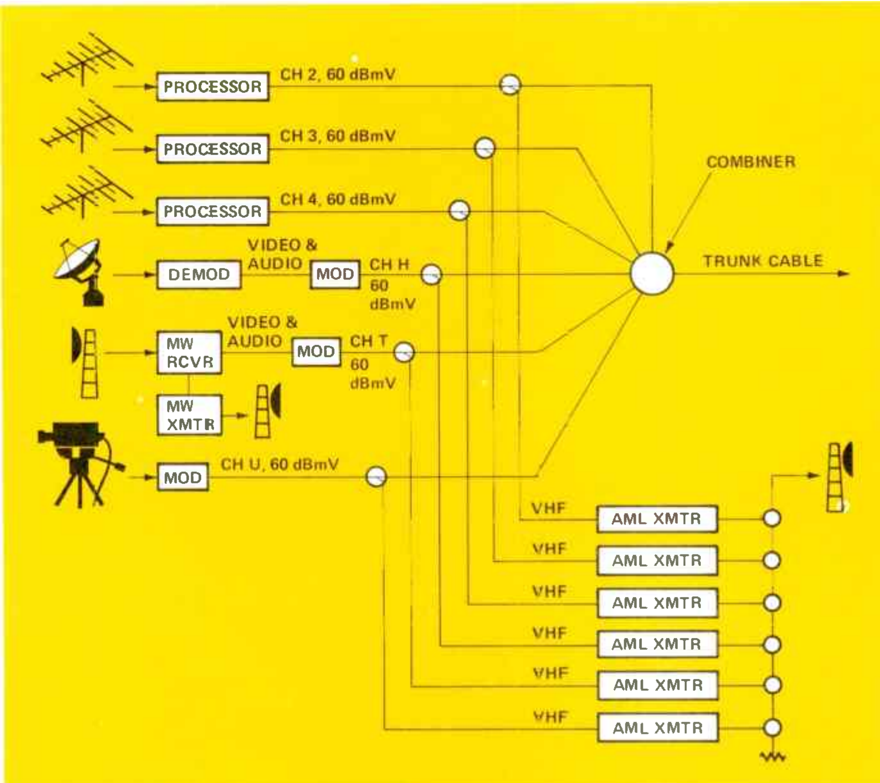


Figure 3. Block diagram for a head-end station.

from a distant location. Also assume strong, local channel 2 and 4 broadcasts. At the antenna, the unwanted channel 2 and 4 signals may more than equal the wanted channel 3 signals. This situation requires filters to trap the channel 2 and 4 signals and to pass channel 3.

The head-end processors compensate for fluctuations in the input signals and provide a high-level signal to the cable. As explained later, it is sometimes not desirable to transmit TV signals over the same channels on which they are received. In this case converters convert the CATV signal to another channel.

Modulators are used to impress studio originated audio and video as well as microwave and satellite baseband signals onto a TV channel carrier. Pilot carriers, for automatic gain control on the trunk, also originate at the head-end.

Figure 4 and 5 are expansions of the AML transmitters shown in Figure 3. Figure 4 is for a single channel transmitter, Figure 5 is for a multiple channel link.

Referring to Figure 4, the AML transmitter consists of a crystal-controlled reference oscillator, a phase-locked oscillator and multiplier, a mixer, two bandpass filters, a klystron amplifier, a circulator and an antenna.

The crystal oscillator controls the frequency of the phase locked oscillator. The output of this oscillator is

Figure 1. Single channel AML.

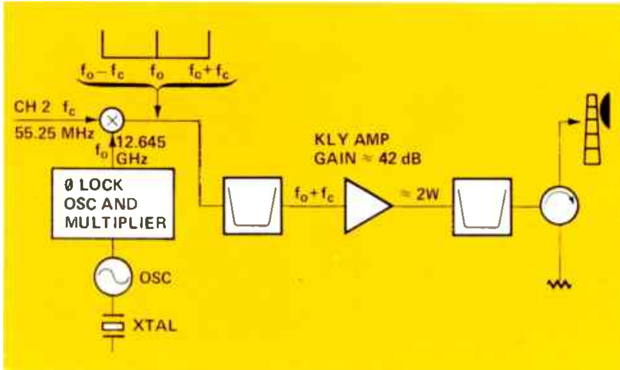
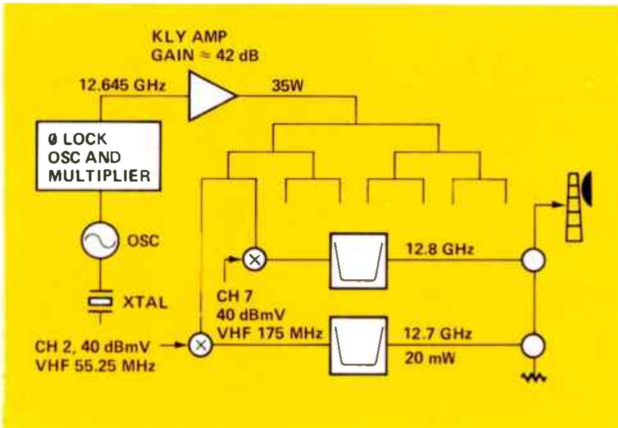


Figure 5. Multi-channel AML.



connected to the input of a multiplier chain to produce a final output, f_O, in the 12 GHz band (12.645 GHz in the figure). This signal is connected to one input of a mixer.

The other input to the mixer is a television channel at a frequency f_C (channel 2, 55.25 MHz in the figure). The output of the mixer is a conventional amplitude modulated wave with a center frequency f_O, an upper sideband $f_O + f_C$, and a lower sideband $f_O - f_C$.

The mixer output is passed through a bandpass filter which removes the lower sideband and the carrier. The output of the filter is a single-sideband, suppressed-carrier signal at a frequency of $f_O + f_C$, 12.7 GHz in our example. This signal is amplified by a klystron which has a gain of about 42 dB. The 2 watt output is connected through a second bandpass filter and a circulator to the antenna.

Figure 5 is a multichannel arrangement of an AML system. A crystal-referenced, phase-locked, oscillator-multiplier is also used in this arrangement. However, the output is now connected directly to the klystron amplifier. The amplifier output is a 12.645 GHz, 35 watt signal.

The klystron output is connected to the input of a series of magic tees. A magic tee is essentially a hybrid rf power splitter. The final magic tee outputs are connected to the inputs of different mixers.

Various television channels are connected to the other inputs of these same mixers. The output of each mixer is again an amplitude modulated wave consisting of the oscillator frequency and both sidebands. This signal is filtered to remove the lower sideband and oscillator frequency. The filter output is connected to the antenna through a circulator arrangement. The final product is a group of single-sideband, suppressed-carrier, frequency-division-multiplexed signals. For an 8-channel system, the power output would be about 20 milliwatts per channel.

For the Channel 2 and Channel 7 signals shown in Figure 5, the nominal frequencies would be approximately 12.7 and 12.8 GHz, respectively. These microwave signals are transmitted to a subsidiary head-end where they are down-converted to VHF, by a process which is the reverse of the up-conversion shown in Figures 4 and 5. The recovered TV signals are amplified and recombined for application to the cable. Thirty-five or more television channels may be offered by a modern CATV system.

The CATV frequency spectrum is shown in Figure 6, and the TV channel frequency assignments are shown in Table 1. Each channel has a 6 MHz bandwidth.

Modern CATV amplifiers have a bandwidth of approximately 250 MHz. So, theoretically, 41 channels could be transmitted over the cable. However, this theoretical maximum is reduced to about 35 channels, to avoid possible interference with aircraft navigation and allow for fm radio. There are systems with 36 channels in operation today.

The FCC requires new CATV systems serving urban areas (largest 100 markets) to have a capability of 20 channels. The significance of these numbers can be appreciated by comparing them to the standard CATV system of the 1960's which had a capacity of 12 channels. Earlier systems had even less capacity.

Regulated, 30 or 60 volt ac power is also multiplexed with the rf signal and carried on the cable. The ac provides primary input power to the dc power supplies in the line amplifiers. Head-end stations are also furnished with a variety of test and monitoring equipment for quantitative and qualitative signal measurements.

Cable Subsystem

The combined final signal is delivered to subscribers by a coaxial cable network. The network consists

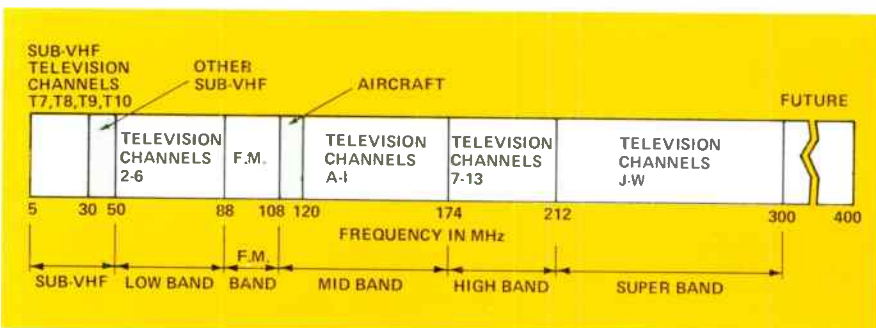


Figure 6. CATV Frequency Spectrum.

Table 1. TV Channel Frequencies.

CHANNEL	FREQ RANGE IN MHz	CHANNEL	FREQ RANGE IN MHz	CHANNEL	FREQ RANGE IN MHz
SUB-VHF	5.75-47.75	D	138-144	N	240-246
T-7	5.75-11.75	E	144-150	O	246-252
T-8	11.75-17.75	F	150-156	P	252-258
T-9	17.75-23.75	G	156-162	Q	258-264
T-10	23.75-29.75	H	162-168	R	264-270
T-11	29.75-35.75	I	168-174	S	270-276
T-12	35.75-41.75	HI-VHF	174-216	T	276-282
T-13	41.75-47.75	7	174-180	U	282-288
LO-VHF	54-88	8	180-186	V	288-294
2	54-60	9	186-192	W	294-300
3	60-66	10	192-198	UHF	470-890
4	66-72	11	198-204	14	470-476
5	76-82	12	204-210	20	506-512
6	82-88	13	210-216	27	548-554
FM	88-108	SUPER-BAND	216-300	35	596-602
MID-BAND	120-174	J	216-222	42	638-644
A	120-126	K	222-228	50	686-692
B	126-132	L	228-234	60	746-752
C	132-138	M	234-240	70	806-812

of trunk lines, distribution lines and subscriber drops.

The coax used for the trunk cable is typically 0.5 to 1.0 inches in diameter. Distribution cable is 0.41 to 0.5 inches in diameter and drop cable is 0.25 to 0.33 inches in diameter. Larger cable is used for the trunk because it has less attenuation per unit length than smaller cable. The trunk is the longest cable run (up to 10 miles).

Distribution cable runs are substantially shorter than trunks and subscriber drops are the shortest of the three. Furthermore, small diameter cable is the most flexible, an important consideration for cable routing into and inside a home. Table 2 lists some characteristics of two typical coaxial cables used for CATV.

There are substantial differences between these cables and ordinary coax. Ordinary coax consists of a copper center conductor, a solid dielectric, a braided copper outer conductor and a protective outer jacket.

The CATV trunk cable, listed in Table 2, consists of a copper-coated aluminum center conductor, a foam polyethylene dielectric and a solid aluminum tubing outer conductor. The cable is available with or without a protective outer jacket. Significant weight savings are realized by the copper-coated aluminum center conductor, with little sacrifice of conductivity, since signal currents flow near the surface, due to "skin effect."

Referring back to Figure 1, the signals are attenuated as they travel down the trunk from the head-end to the terminating bridger. Trunk amplifiers are placed at intervals along the trunk to restore the signal to its original level. These amplifiers are probably the most critical element in the cable system, so they will be described in detail later.

At convenient points along the trunk, the line is bridged with another amplifier which feeds signals to a distribution cable. Whenever practical these bridging amplifiers are mounted in the same housings as the trunk amplifiers, for reasons of economy and to minimize trunk-cable interuptions.

Table 2. Parameter III Coaxial Cable Dimensions.

	1,000 CA SERIES		500 CA SERIES	
	INCHES	MILIMETERS	INCHES	MILIMETERS
CENTER CONDUCTOR DIAMETER	0.225 ±0.002	5.69 ±0.05	0.1125 ±0.001	2.86 ±0.03
NOMINAL DIAMETER OVER DIELECTRIC	0.890	22.61	0.450	11.43
DIAMETER OVER SHIELD	1.000 ±0.015	25.40 ±0.3	0.500 ±0.007	12.70 ±0.18
NOMINAL SHIELD THICKNESS	0.055	1.40	0.025	0.64
JACKET VERSIONS				
NOMINAL DIAMETER OVER JACKET	1.10	27.94	0.600	15.24
NOMINAL JACKET WALL THICKNESS	0.050	1.27	0.050	1.27
ATTENUATION @ 68°F (20°C)				
FREQUENCY (MHz)	MAX. (dB/100 FT)	N/km	MAX. (dB/100 FT)	N/km
5.0	0.09	0.34	0.16	0.60
10	0.13	0.49	0.23	0.87
25	0.21	0.79	0.36	1.36
50	0.30	1.13	0.51	1.93
55.25 (Ch.2)	0.31	1.17	0.54	2.04
83.25 (Ch.6)	0.39	1.47	0.66	2.49
100	0.42	1.59	0.74	2.79
108	0.44	1.66	0.75	2.83
150	0.52	1.96	0.90	3.40
175.25 (Ch.7)	0.57	2.15	0.98	3.70
200	0.61	2.31	1.05	3.96
211.25 (Ch.13)	0.62	2.34	1.09	4.12
250	0.68	2.57	1.20	4.53
300	0.75	2.83	1.31	4.95

Courtesy Comm/Scope Co.

When necessary, distribution amplifiers are used to maintain the signal level along the distribution cable. The cable is tapped close to the customers premises and brought in by drop cable. A grounding block is used at the point of entry to assure that the cable shield is firmly bonded to the building grounding system.

If the structure is a single family residence, the cable is connected to the input of a converter or through a matching transformer to the TV set. The transformer matches the 75 ohm, unbalanced cable to the 300 ohm, balanced TV input. The use of converters is discussed later.

Other equipment which might be installed on the distribution cable or customer's premises includes, multitaps, passive splitters, directional couplers and indoor amplifiers. Multitaps, consisting of directional couplers and hybrid splitters, are used to connect more than one drop cable to a single point on the distribution cable. Passive splitters and directional couplers are used to divide the signal on distribution and drop cables. Indoor amplifiers are used when the drop signals must be further amplified, as in an apartment house.

Detailed Discussion

The foregoing paragraphs describe the cable distribution system in general terms. The following paragraphs describe the system's components in greater detail, after an explanation of dBmV, which is the standard unit of level measurement for CATV. The term dBmV means dB referenced to a level corresponding to 1 millivolt rms across 75 ohms. In other words:

$$\text{dBmV} = 20 \log_{10} \frac{\text{Volts in rms mV}}{\text{ref level (1 mV rms)}}$$

OR

$$\text{dBmV} = 20 \log_{10} \text{rms mV}$$

when the voltage is measured across an impedance of 75 ohms.

The 1 millivolt reference is used because it is the approximate input signal level an ordinary television receiver requires to produce a noise free picture.

Since 75 ohms is the impedance at almost every point in the cable system, dBmV is a very convenient unit for measuring and comparing signal levels. A tunable, frequency-selective voltmeter can be used for all level measurements. The conversion to dBmV is relatively easy. Table 3 lists some voltage measurements and their dBmV equivalents.

Note that 1 millivolt across 75 ohms is 0 dBmV. This is a finite, absolute quantity. Any voltage across 75 ohms which is greater than 1 millivolt can be expressed as +dBmV; any voltage less than 1 millivolt across 75 ohms can be expressed as –dBmV.

People in the telephone industry are familiar with decibels referenced to one milliwatt (dBm) as a signal-level measuring unit. The difference between the two reference levels is:

$$0\text{dBmV} = -48.75 \text{ dBm}.$$

There are some important things to remember about dB and dBmV as applied to CATV systems. The first thing is that dB is used to express gain or loss, it is a ratio and not a definite quantity. On the other hand, dBmV is a measurement of signal level and is referenced to a standard, 1 millivolt across 75 ohms. Another thing to remember is that dB may be added to or subtracted from dBmV, but dBmV may not be added to or subtracted from dB.

Returning to the discussion of the cable distribution system, trunk amplifiers are installed at regular intervals (about every 1800 feet) along the trunk. The purpose of these amplifiers is to restore and equalize the signal levels which have been attenuated by the coaxial cable. The amplifier gain exactly compensates for the cable loss, so the combination is said to have unity gain.

Figure 7 is a block diagram showing the essential circuitry of a basic, manual, trunk amplifier. This unit amplifies and equalizes signal levels over its complete band of operation. It compensates for cable attenuation at one specific temperature (cable rf attenuation is temperature dependent).

The rf input signals pass through a plug-in attenuator and equalizer to the first amplifier stage. The attenuator is used where cable lengths between amplifiers is quite short. It prevents amplifier overload. The equalizer is used to partially equalize signals over the frequency range, since cable attenuation increases with frequency.

A passive equalizer is actually an attenuator with an attenuation slope opposite to the attenuation slope of cable. As shown in Table 2, cable attenuates high frequencies more than low frequencies. The equalizer attenuates the lows more than the highs, to equalize the signal levels at the amplifier input.

The first two rf stages are broadband amplifiers in a common emitter configuration. They are followed by a variable attenuator. The third rf stage uses a variable resistor in the collector-

Table 3. dBmV/Microvolt Chart.

dBmV	µV	dBmV	µV	dBmV	µV	dBmV	µV
−40	10	−20	100	0	1,000	20	10,000
−39	11	−19	110	1	1,100	21	11,000
−38	13	−18	130	2	1,300	22	13,000
−37	14	−17	140	3	1,400	23	14,000
−36	16	−16	160	4	1,600	24	16,000
−35	18	−15	180	5	1,800	25	18,000
−34	20	−14	200	6	2,000	26	20,000
−33	22	−13	220	7	2,200	27	22,000
−32	25	−12	250	8	2,500	28	25,000
−31	28	−11	280	9	2,800	29	28,000
−30	32	−10	320	10	3,200	30	32,000
−29	36	− 9	360	11	3,600	31	36,000
−28	40	− 8	400	12	4,000	32	40,000
−27	45	− 7	450	13	4,500	33	45,000
−26	50	− 6	500	14	5,000	34	50,000
−25	56	− 5	560	15	5,600	35	56,000
−24	63	− 4	630	16	6,300	36	63,000
−23	70	− 3	700	17	7,000	37	70,000
−22	80	− 2	800	18	8,000	38	80,000
−21	90	− 1	900	19	9,000	39	90,000
						40	100,000

0dBmV = 1,000 µV (1.0 mV) ACROSS 75 OHMS

to-base feedback path, to provide variable tilt for further cable equalization. This is followed by a second variable attenuator and two more wideband rf stages.

The use of five stages of amplification and ganged gain controls provides excellent frequency response over the 50 to 300 MHz band (± 0.2 dB ripple). The gain range is from 18 to 31 dB. A gain setting of about 22 dB is typical of many systems. In any event, the gain is set to compensate for the losses in the preceding cable section.

Total Automatic Control Trunk Amplifier

As previously stated, the circuit in Figure 7 compensates for cable attenuation at one specific temperature. In other words, once the gain and slope are adjusted for best operation, optimum amplifier performance will be present only while the cable is at the temperature it was when the adjustments were made.

Typically, cable attenuation increases about .12 percent per degree Farenheit of temperature increase.

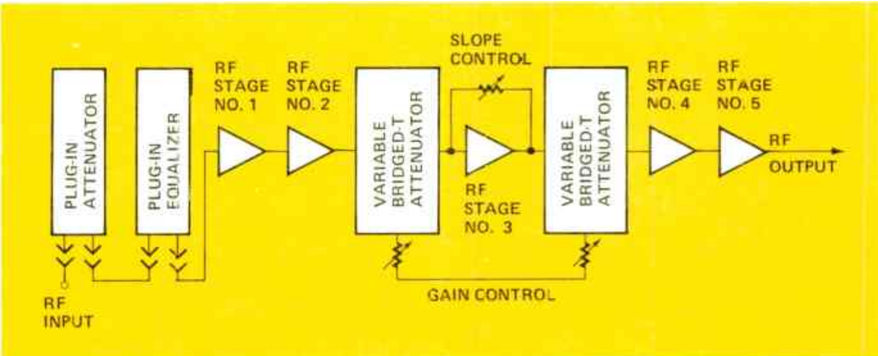


Figure 7. Basic trunk amplifier module.

Conversely, the attenuation decreases by the same percentage per degree of temperature decrease.

Referring to Table 2, the 1.000 CA series cable attenuates channel 2 signals approximately 5.6 dB per 1800 feet at 68 degrees Farenheit. The same cable at the same temperature attenuates channel 13 approximately 11.2 dB.

If the temperature increases 50 degrees the attenuation will increase .12 x 50 = 6%. The attenuation of channel 2 will be 1.06 x 5.6 ≈ 5.94 dB. The attenuation of channel 13 will be increased to approximately 11.9 dB.

If the temperature decreases the attenuation decreases proportionaly. If the temperature decreases 50 degrees, the cable attenuation will decrease 6%. For the 1800 foot cable we are discussing the channel 2 attenuation at 18 degrees F is approximately 5.3 dB and for channel 13 approximately 10.6 dB.

Let us consider a hypothetical trunk with amplifiers of the type shown in Figure 7 installed at 1800 foot intervals along the cable. The amplifiers have been adjusted at 68°F (i.e. the sum of the cable loss and amplifier gain equals unity at 68°F).

Now let's consider the operation at 18° Farenheit. Channel 2 signals, from the head-end to the first amplifier, are 0.3 dB higher than normal. The channel 13 signals are 0.6 dB higher. The passive equalizer and flat gain amplifier will not change this relationship. The amplifier output signal will be high by the same amount as the input signal. The same effect occurs in the second cable section. The input and output of the second amplifier will be high by twice the increase of the first amplifier. The increase in level is accumulative. After a few sections of cable, the amplifiers will be overdriven and severe performance degradation will result.

On the other hand, if the cable temperature increases substantially above 68 degrees, the attenuation of each section will increase. The effect will again be accumulative and the signal will be unusable after a few sections.

The problem is solved by using "Total Automatic Control Amplifiers" which are also known as dual pilot or automatic level and slope (ALS) amplifiers. Figure 8 shows the circuitry which is added to the basic amplifier to provide automatic control.

The input signal to this circuit is brought from the basic amplifier through a 10 dB directional coupler. At the coupler output two carrier pilots, one high frequency and one low frequency, are separated from the signal by filters and then combined to form the input of a four stage rf amplifier. This high-gain amplifier is wideband and very stable.

The pilots are separated again by filters at the amplifier output. The high frequency pilot is connected to the input of a gain control detector. The low frequency pilot is connected to the input of a slope control detector. The individual outputs of the detectors are compared to dc reference voltages. Any deviation from the reference serves as an error signal.

Any error signal from the gain control detector is connected to the input of a dc amplifier which has two outputs. These outputs are used to vary the current of PIN diodes in the two variable attenuators of the basic amplifier. The PIN diode resistances change in a direction to maintain a constant amplifier output at the high pilot frequency.

The output of the slope control detector is also compared to a dc reference. Any error signal is amplified and used to vary the resistance of a PIN

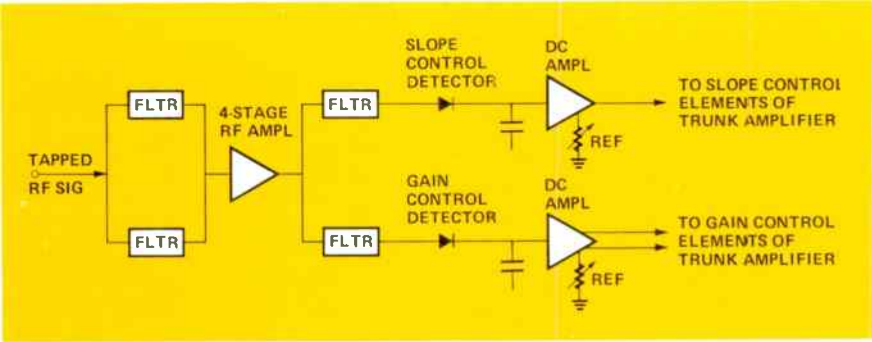


Figure 8. Automatic level and slope control circuit for total automatic control amplifier.

diode in the feedback path of the third rf amplifier. This amplifier's gain is sloped to maintain a constant level at the low pilot frequency.

As a result, even though absolute changes in cable attenuation with temperature are also a function of frequency, the automatic control circuitry acts to change the amplifier gain and slope to maintain a substantially constant level and tilt at the output.

Again referring to Figure 1, bridging amplifiers are used to connect signals from the trunk to the distribution cable. Bridging amplifiers cover the same frequency range as trunk amplifiers but their operating requirements are less stringent, as far as noise figure is concerned. Also, they work at higher levels. So, their individual distortion and noise contributions are greater than those of a trunk amplifier. However, bridging amplifier performance is more than adequate for its intended purpose.

The bridging amplifier's output is divided by a power splitter to provide signals for up to four distribution cables. It is interesting to note that the amplifiers can drive a greater total length of cable, when the output is split into several cables which fan out in different directions.

Taps are placed along the distribution cable to provide signals to the subscriber drop cables. Each tap uses a directional coupler to extract a small amount of energy from the distribution cable. The cable attenuation also dissipates signal energy.

When the signal on the distribution cable becomes too low to supply a tap, a distribution amplifier is installed. This amplifier raises the signal level high enough to extend the length of the distribution cable and supply additional subscriber drops. Two or three distribution amplifiers may be connected in series along a distribution cable run.

The output levels, and therefore the distortion products, of bridger and distribution amplifiers are much greater than those of trunk amplifiers. A combination of a bridging amplifier and three distribution amplifiers may produce as much distortion as twenty to thirty trunk amplifiers. The limiting factor is: The accumulated distortion, from all sources, must not reach an amount which will prevent a subscriber from receiving quality video.

Subscriber Drops

The subscriber drop is the final link in the distribution system between the head-end and a subscriber's television receiver. A drop starts at an output port of a distribution line tap. A drop cable picks up the signal at that point and carries it to the subscriber's premises. At the TV receiver, a matching transformer matches the 75 ohm cable to the 300 ohm receiver input.

Distribution line taps may serve from one to eight subscribers. The basic tap consists of a directional coupler, a through-path for the cable, an isolation network including an AC power blocking capacitor, and an output port. Multiple outputs are provided by adding separate tap and isolation circuits for each output or by using a single power splitter to divide the basic output port signal into several paths. In either case all the circuitry is encased in one housing.

Insertion loss, coupling loss and isolation loss are terms commonly associated with taps. Insertion loss is the amount of loss the tap installation adds to the distribution cable, coupling loss is the loss from the input to each output of the tap. Isolation loss is the signal loss between each of the multiple outputs.

The drop cable has the least diameter and greatest attenuation of all the coax used in the distribution system. The high attenuation is acceptable because the cable runs rarely exceed 200 feet.

Care must be used to preserve the cable integrity and continuity at the drop. This is particularly true in areas where strong radiated signals are present. A faulty cable can act like an antenna to bring in external signals which interfere with the desired signals on the cable.

Special cable is available for use in areas where this problem is particulary troublesome. A cross-section of one such cable shows six concentric layers (see Figure 9).

Matching transformers are used to match the 75- ohm unbalanced coaxial cable to the 300- ohm, balanced TV input. These transformers usually include AC blocking capacitors. Some matching transformers also contain high pass filters to eliminate low frequency interference. These are particularly useful in the two-way systems discussed later. The filters are also useful in preventing interference from CB radio.

Converters

Converters are used to convert any signal on the cable to one standard VHF channel. The television set remains tuned to this channel and the converter tuner is used to select other channels. Since the cable and converter are carefully shielded and the single VHF channel is one that is not used for local broadcasting, interference problems are greatly reduced. Eliminating interference is one reason for using converters.

Another, perhaps more compelling, reason for using converters is to increase channel capacity. An ordinary television receiver has a VHF tuning capacity for 12 channels. However, all of these channels may not be available for cable use.

In the past, channels which were broadcast locally were not usually placed directly on the cable. The difference in propagation velocity between signals through cable and over the air causes a time differential, between these signals, at the receiver input. Ghosting of the image results. The common practice used to be to translate local broadcasts to adjacent channels for cable transmission. This was not very satisfactory in areas where four or more channels were broadcast. The translation of four channels left only four channels remaining for all other signals.

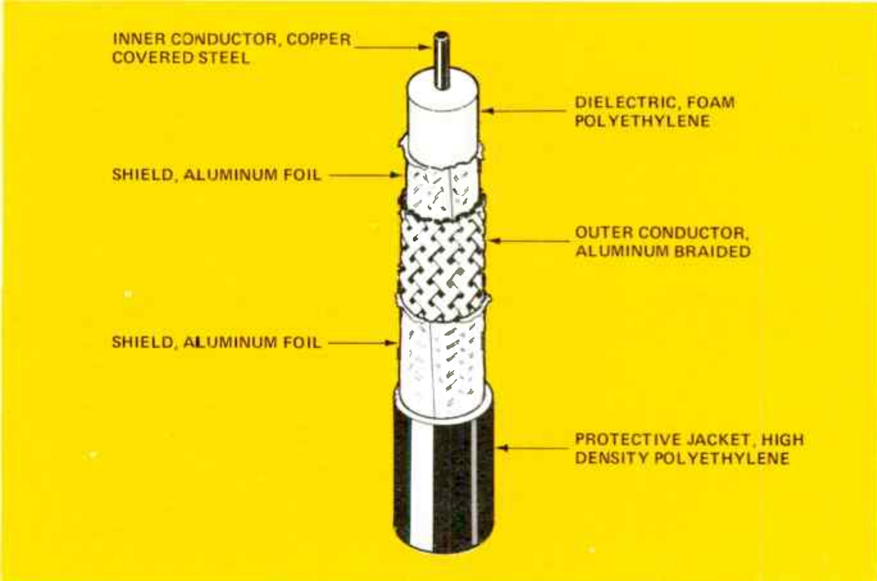


Figure 9. Special drop cable for use in areas with strong broadcast signals.

Today, the common practice is to send local signals over the cable on the same channel frequency used to transmit them over the air. In fact, the FCC discourages the translation of local broadcasts to a different channel. Each case must be justified to the commission before it will approve the translation. The simultaneous transmission of the same frequencies, on cable and over the air, established the need for the special drop cable and careful installation previously described.

Given the fact that modern systems have a capacity of 35 or more channels and that the FCC requires that new systems for the largest markets must have a minimum capacity of 20 channels, the use of converters seems almost mandatory in metropolitan areas. A modern converter can translate up to 40 channels to a single VHF channel.

It is true that several currently marketed television receivers have the tuning capacity to accommodate cable transmissions. However, cable technology and demands for increasing service are not standing still. It is doubtful that the replacement cycle for home receivers will ever equal the rate of change of cable services. So, placing the tuning capability in the converters seems a logical choice.

From the cable operator's viewpoint, the converter has the additional advantage of providing secure pay television service. The pay channels are scrambled at the head-end and descrambled in the converter at the subscriber end. Modern converters can translate from one to three pay channels in addition to more than 30 regular channels. The revenues from pay TV easily defray converter costs.

This was not true when converters were first introduced. In those days many system's operators could hardly afford the capital out-lay required to provide each subscriber with even a modestly priced converter. The problem was aggravated because converters were often damaged or lost. Overriding cost considerations forced the acceptance of marginal design and components.

Consequently, early converters often had inadequate bandwidth which caused picture degradation and excessive frequency drift which caused poor selectivity and made frequent retuning necessary.

Modern converters have overcome these problems. For example, Sylvania's model 4041 programmable converter has an input bandwidth of 52 to 300 MHz. It can convert up to 40 channels to either VHF channel 3 or 4.

Tuning is accomplished by a digitally-controlled, phase-locked-loop, frequency synthesizer. Because the frequencies are referenced to a crystal controlled oscillator, converter fine tuning is not required.

The channel selector has been separated from the rf processing electronics and placed in a hand held case resembling a calculator. The case is moisture resistant and made of high impact plastic. The key pad uses touch-sensitive, membrane-type, key switches. Light emitting diodes are used to provide a two-digit channel indicator.

Channels 37, 38 and 39 are reserved for pay TV or other special channels. They can be assigned, at the service shop or factory, to any frequency between 50 and 300 MHz. When one of these channels is selected, the selector unit provides an output to turn on the proper descrambled and tune to the channel frequency. Each channel has a separate output to allow up to three-tier pay service.

A microprocessor is also included in the unit. It has sufficient memory to store up to 10 channels selected by the subscriber. He can place his favorite channels in memory by simply holding the CHAN ENT switch while entering the channels in sequence. At any subsequent time, these channels can be recalled and sequenced by pressing a single key.

The channel selector unit is virtually indestructible. About the only way it could be damaged would be to deliberately stab it with a sharp instrument. The rf processing unit is also cased in high impact plastic.

Two Way Systems

In February 1972, the FCC issued a Report and Order requiring new, major CATV systems to provide a "technical capacity for non-voice return communications" from customers' locations. The signal path from the head-end to the subscriber is referred to as "downstream"; the path from the subscriber to the head-end is referred to as "upstream."

Two methods are most frequently used to provide this capacity. One method uses separate cables for each direction of transmission. The other "bidirectional" method uses a single cable with different frequency bands for each direction of transmission.

The single cable method uses the 5 to 30 MHz, sub-VHF portion of the spectrum, to provide four channels for upstream signals, as shown in Figure 6. The downstream signals use the 50 to 300 MHz portion of the spectrum to provide 30 or more channels, as previosly described.

Coax is bidirectional but amplifiers are not. So, separate amplifiers must be provided for the upstream signals. These amplifiers are represented by the small black triangles in Figure 1.

Three types of amplifiers are used: trunk, bridging and distribution. Trunk amplifiers have more stringent operating requirements and operate at lower levels than the other two. Some trunk amplifiers have provisions for operation in either of two modes, high gain or low gain. High gain is used when the upstream traffic is video. Low gain is used for data. The gain is 16 dB minimum in the high mode and 6 dB minimum in the low mode. Essentially the same amplifier is used for bridging but it provides 20 dB minimum gain in the high mode.

Distribution amplifiers are used when the distribution cable run is long enough to require amplification of the sub-VHF signals before they are impressed on the trunk. The attenuation of all sections of trunk cable are usually made equal by building out short sections with attenuators. So, the upstream inputs from the distribution cables to the trunk should also be equal. They should also allow for low level operation of the trunk amplifier to prevent distortion. These purposes are served by providing attenuators at the outputs of the distribution amplifiers. Various attenuators and equalizers, including thermal types, are available for all three types of upstream amplifiers.

A return passive network is used to provide a path around the downstream amplifiers, when upstream amplification is not required. For example, a line extender amplifier might be installed at a point in the distribution cable within a few hundred feet of a subscriber's premises. Signals originated by the subscriber would not require amplification at that point.

The return passive network is formed of bandstop filters to maintain downstream amplifier stability by blocking the downstream signals, and bandpass filters for upstream signals. Equalizer networks may also be included to compensate for cable slope.

Figure 10 is a photograph of a Trunk Transportation Station for a bidirectional system. The term "station" in CATV language has the same meaning as "repeater" does in telephone language.

Referring to the figure, there are four plug-in modules in the housing. From top to bottom they are; an upstream trunk amplifier, a downstream trunk amplifier similar to the one shown in Figure 7, an ALS module similar to the one shown in Figure 8 and a bridging amplifier to feed distribution cables. The power supply and associated transformer are mounted in the cover.

The housing is made of die-cast aluminum. The conductive gasket prevents electro-magnetic radiation and provides a weather-proof seal. The housing may be suspended from a messenger cable or equipped with hardware for pole or pedestal mounting.

Two Cable System

Two cable systems run all the way from a complete upstream coaxial system, which essentially duplicates the downstream system, to simply providing a telephone pair for upstream traffic. The pair system is cheapest but can only handle voice or data traffic, not video.

A completely dual coaxial system has the greatest return channel capacity but is the most expensive. However, the cost or stringing two cables at the same time, probably will not be greater than 50% more than the cost of stringing a single cable, since the difference in labor costs is not substantial.

Note that the FCC Report and Order requires a "technical capacity", rather than a "capability" for two-way communications. Generally, the industry has interpreted this to mean that new installations should not preclude future two-way transmissions. For example, station housings on a single cable system should allow mounting space for upstream amplifiers, filters,

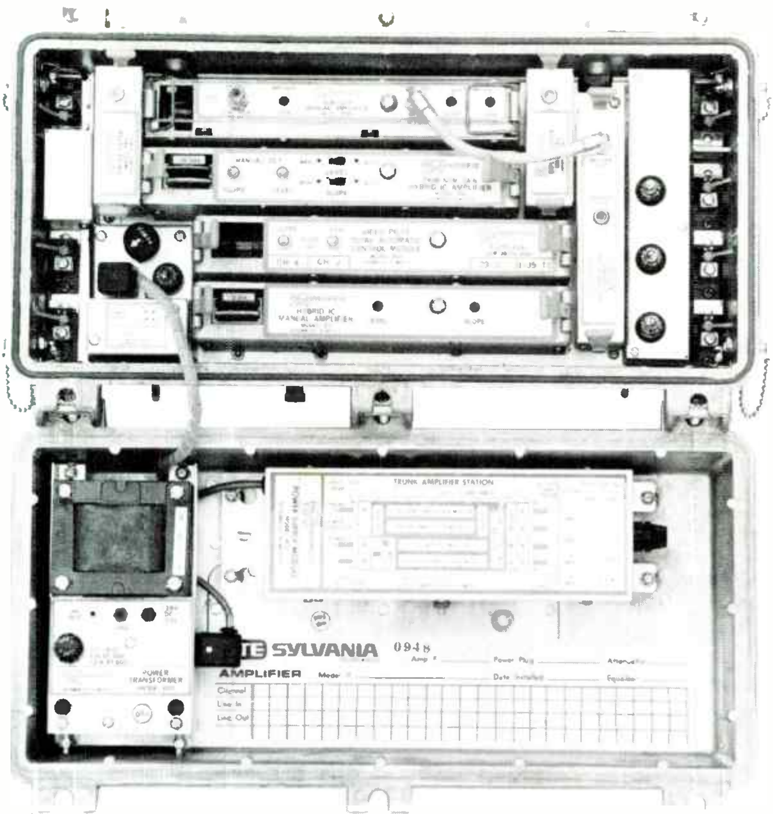


Figure 10. Trunk amplifier station.

Courtesy Sylvania CATV

etc., but these devices need not be installed until needed.

Viewed in this light, installation of a dual coaxial system, with installation of electronic components postponed until required, might prove most economical in the long run. This statement assumes that the demand for broadband, two-way communications becomes great enough to make the service profitable. To date this has not been so. With few exceptions, two-way communications systems have not paid their own way.

One exception is the data communications and leased channel services which Manhattan Cable provides business customers. The company uses two of its 36 channels for this service. One channel is used for downstream and the other is used for upstream transmissions. The 6 MHz per channel bandwidth is more than adequate for the high speed data service. The system is bidirectional. The trunks used for this service are equipped with amplifiers for each direction of transmission.

Another successful application of two-way systems involves installations in new, "planned" communities. The system consists of a two-way cable system, a home terminal and a central, computer-controlled data system.

The terminals provide security, fire alarm and medical alert information. They are polled by the computer and use a multi-frequency, multi-code scheme for terminal identification etc... The system can be adapted to distributing pay TV with charges on a per program or per channel basis.

The use of computer controls has many advantages which make it attractive to CATV operators. One of these is the ability to turn service on or off, without requiring a technician to visit the customers premises.

This and other uses of computers in CATV systems will be discussed in Part 2 of our CATV series. The second part will also describe possible future equipment and system developments in the CATV industry.

BIBLIOGRAPHY

1. Lowell Williams – *Concepts of Distribution: The Basics of Cable Television* – TV Communications, November 1975 Communications Publishing Corporation, Engelwood, Colorado.

2. Allen C. Maltz – *Cable Television – Its Role in Data Transmission, A Case Study at Bankers Trust Company* – April 1976, The National Cable Television Association, Washington, D.C.

3. D. Lieberman – *Wideband Distribution Equipment* – July, 1971 GTE Sylvania Cable Television, El Paso, Texas.

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