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Cable Television Handbook

EUGENE R. BARTLETT

**Solve wide-ranging technical and
operational problems**

**Install and service new types of cable,
wiring, hubs, and transmission and
control methods**

Clear coverage of new FCC regulations

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CHAPTER **2**

**Tree/Branch
Cable Systems
and Network
Topology**

Introduction

The basic idea of the cable television system was that the central antenna system would be shared among connected subscribers willing to pay a monthly fee. The head-end, as it was known and still is, was the source of the signals making up the basic service. The head-end was usually located on a hilltop, tall building, water tank, or steel tower located out of town away from the subscriber homes. The basic off-air received television signals were amplified, filtered, adjusted in level, and combined and delivered by the cable amplifier cascade to subscribers. This elementary topology was known as the tree-branch cable system. The main cable was the trunk system from the head-end to the town where the cable branched down the streets to the subscriber's homes.

A One-way System, Two-way Considerations

The basic tree-branch system consisted of cable-amplifier sections feeding signals one way from the receiving head-end tower site to subscribers. Many early cable operators were aware of possible two-way operations by splitting the service signal band between downstream and upstream service and installing upstream amplifiers. Such early thinking was basically wishful thinking mainly because of system problems such as temperature stability, signal level control, and amplifier noise and distortion. Basically, early systems were one-way systems and even today many systems are still essentially one-way.

Product Delivery, Many Channels The bread and butter of cable systems operation was, and in many cases still is, the delivery of many cable television channels containing a variety of program choices to subscribers. When more channels were offered and cable system costs increased, subscriber rates were subsequently increased. The concept of program tiering allowed subscribers a choice of programming packages such as news, sports, and movies. The source of these programs came about with the introduction of satellite technology. Presently, the number of program channels available from various satellite systems is enormous.

The two problems cable system operators have in today's market are (1) adequate system bandwidth needed for an increase in channels and (2) making the decision as to what programming will sell best. To repeat, the bread and butter of cable system operations is the delivery of television

programming to subscribers. It was thought at one time that auxiliary services such as electric meter reading and alarm systems would support two-way cable operations. The cost of the reverse system activation is a significant expense compared to projected revenues for the services.

Service Area Specifications The problem of identifying the service area of a cable television system is a difficult one. First and foremost is the fact that the centers of residential population are the criteria for successful subscriber penetration. Unfortunately, the licensing or franchising of municipal authorities may impose requirements that non-productive areas still be served. Also, future areas of residential expansion may not be readily identified, thus necessitating future plant expansions.

Most cable system operators avoided building cable plants in industrial and commercial areas. Thus, many cable operators have had to build more plants to provide information services to these areas. The location of the subscriber office area, the technical maintenance area, and the head-end location can also be factors in planning and specifying the service area.

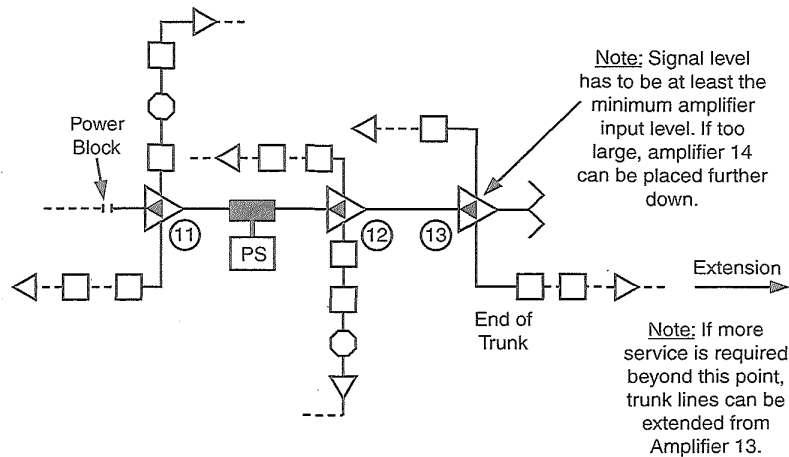
Essentially, the service area has to be specified before financing and construction plans can commence. Thus, as the saying says, do the homework carefully and diligently. Technical people as well as managerial people should be involved in this decision-making process. By estimating the miles of the plant, the feeder-to-trunk ratio, and the number of program channels, the cost per mile of plant and the head-end costs can be projected. Now the basic revenue can be projected, producing a cash-flow or financial pro-forma to offset debt and support the venture. This process is complicated and has to be carefully completed before any construction schedule can be made.

Expansion of Feeder Criteria The proper plant design required to serve the more heavily populated area of many communities should not be so trunk-restrictive that businesses will box themselves in by making it difficult to extend the distribution cables to new areas. In short, a system does not want to run out of trunk that can restrict extending the feeder plant. It must be remembered it is the feeder or distribution plant that connects the cable system to subscribers. The trunk is considered as the transportation system bringing the service to the distribution plant.

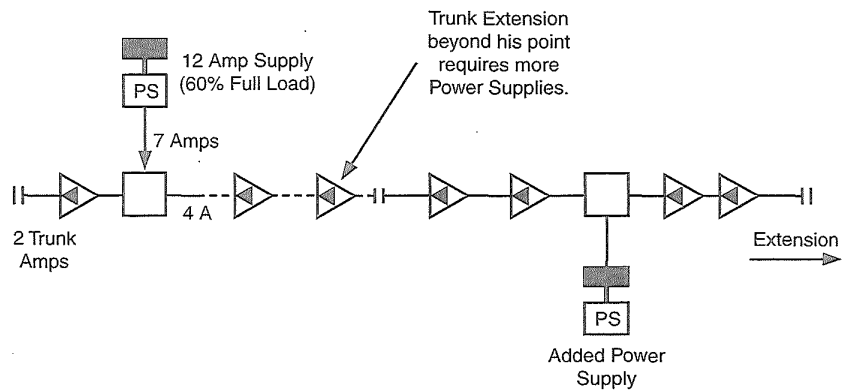
By now, it should be obvious that the feeder/distribution plant makes the money, while the trunk cable plant is a necessary cost. The extension of a feeder plant adds more subscribers, thus improving the cash flow. Since the cost of extending a feeder plant is significantly less than the trunk plant costs, a careful analysis has to be made when extending a plant. Often a

Figure 2-1

Trunk extension
required to extend
service area

**Figure 2-2**

Added trunk requires
added system power
supplies



significant extension of the feeder plant means adding some more trunk plants. This is shown in Figure 2-1, where feeder plant amplifier cascades are limited to two amplifiers in a cascade off the bridger trunk amplifier.

Adding more cable amplifiers to a system also means that system powering may have to be restructured with the addition of more power supplies and resegmenting the powering system. Repowering such plant additions is shown in Figure 2-2.

Television Receivers

The main receiving device of a cable television system is the subscriber's television receiver. These receivers can range from new to almost museum-

piece television sets. However, since television sets have an average life of about 10 years, it is fairly safe to assume that most subscriber sets range from new to 10 years old. The median age range is estimated to be about four or five years old. Also, almost all of the television sets are color TV sets.

Since cable systems carry the service in standard NTSC VSB format, the television receives the signals and makes the channel selection by frequency-synthesized tuners, the same as if it were an off-air TV station. Since cable system channels can be offset in channel frequencies in the HRC or IRC format, television sets made in the last 10 to 12 years have a switch often appearing on the rear cover or selected by the remote control labeled Cable 1 or Cable 2. This switch controls the action of the channel selector to tune to the desired channel settings.

The present-day television set is devoid of horizontal and sometimes vertical hold controls due to vastly improved circuitry that locks the picture synchronization. Automatic chroma controls and contrast controls keep the pictures at the same color and brightness. The remote control system can usually address all picture quality controls, channel selection, and video source selection, making most of us the so-called couch potatoes.

Integrated circuit technology, circuit board construction, and modular tuning, along with the remote control system, have reduced the cost of television sets drastically. Still the picture tube or the projection system determines the cost of the receiver. All of the electronic systems of a number of present-day television sets are valued at \$40 to \$50. The cabinet and screen/tube system results in most of the cost of a TV set. Since the subscriber's television set is what produces the cable system's picture, it is most important that cable operators make sure the cable installer makes the proper connections to the TV set and instructs and advises the subscriber in getting the most out of the service.

Channel Tuning As stated earlier, the television set has to tune precisely to the cable channels for best signal and sound quality. The noise characteristics of the television set tuner are most critical. The noise figures of early TV sets were quite poor and the UHF portion even worse. As the TV sets improved, the noise figures of the channel-selecting tuners did as well. The IF bandwidth characteristics improved also, which in turn gave better pictures with improvements in the quality of TV receiver design. The picture resolution improved from about 260 lines to about 380 to 400. With the arrival of HDTV, picture resolution will indeed improve again.

Since HDTV will be digital, as proposed and scheduled in the next century, the consumer electronic manufacturers are going to be busy designing, developing, and testing TV sets for this new service. The broadcasting

companies are busy getting new studio and transmitting equipment capable of handling the digital signals, readying the public for HDTV service where no TV HDTV sets exist. The trials of off-air digital television services will be taking place soon. Then maybe the problem areas will be identified. As yet no signal strength parameters, signal-to-noise specifications, or the tolerance-to-multipath reception information has resulted. In short, no one knows if digital television broadcast stations can be received with rabbit-ear antennas or will be back to roof-top antennas.

As far as the cable operator is concerned, questions remain. First, will cable head-ends receive digitally modulated signals from a tower-mounted antenna? Second, will cable systems convert some of the signals to other modulation schemes or to NTSC VSB format? Third, what will be the must-carry rules as set forth by the FCC for broadcast stations transmitting multiple channel digital signals? And the list seems to go on and on.

Channel Converters The channel converter either rented or purchased from the cable operator has traditionally been required to provide cable television channels unable to be selected by standard TV sets. For some early cable systems that placed added programming channels in the so-called mid-band, a simple UHF-up converter was used. This device simply converted the mid-band channels that were spaced from the FM band to VHF Channel 7 to the UHF band (470 to 890 MHz). This block converter, as it was known, connected between the cable and the TV set's UHF terminal, as shown in Figure 2-3.

Since there were nine equivalent 6-MHz television channels spaced in the mid-band, the nine channels, in addition to the 12 VHF channels, resulted in what was known as the 21-channel cable system. At this point in time, available trunk and distribution cables had significant loss at UHF frequencies. Available amplifiers had upper frequency limits of 220 to 300 MHz. The reception of UHF broadcast stations was carried on the cable systems by converting each one of them to one of these nine mid-band cable channels at the head-end. The blockup converter at the subscriber's television set would then convert them back from mid-band to UHF.

Back in the 1970s, the 21-channel cable system offered a decent selection of programming with better reception than most indoor or outdoor antennas. The success of 21-channel systems encouraged the expansion of cable operators to increase the upper frequency limit to 300 MHz. Thus, another 14 television channels were added, making the 35 channel system. This increase in channels beyond the frequency selection capabilities of the television sets of the day made the tunable or frequency-agile set-top converter

Figure 2-3
The block-up
converter

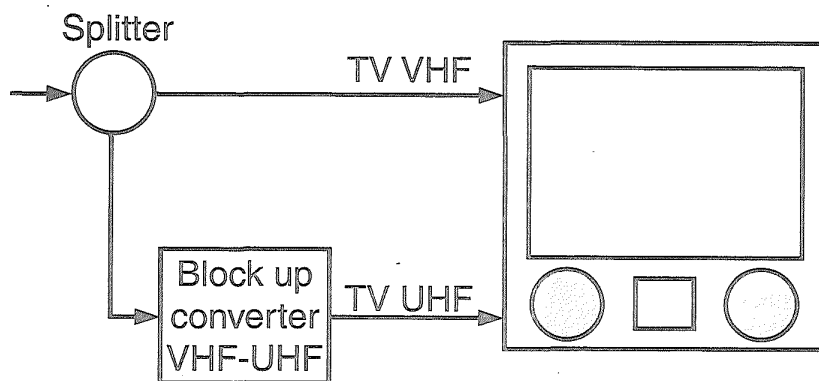
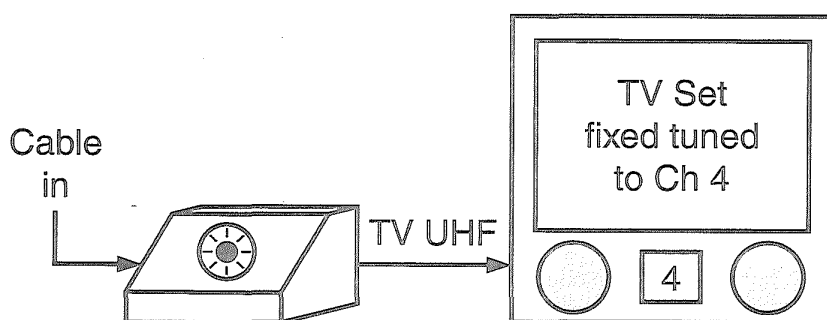


Figure 2-4
Tuneable subscriber
converter



necessary. The method of connecting this device between the cable and the television set is shown in Figure 2-4.

Converters of this type had to have good noise specifications, or low noise, simply because the cable signal has to go through the so-called front end of the converter and then through the front end of the television set, resulting in noise contributions from both sources. These first generation tunable converters required the subscriber to select the desired program on the converter, which translated to a fixed channel (usually channel 3 or 4). This situation essentially defeated the use of the set's remote control. Thus, the first big problem with subscriber devices resulted. A natural progression to increase the upper frequency limit beyond 300 MHz was forthcoming. Thus, the evolution from 52 channels at 400 MHz to 62 channels at 450 MHz to current state of the art systems offering more than 150 channels resulted.

Subscriber Services With the tremendous increase in cable system channel capacity, subscriber service selections became enormous. Many subscribers only wanted a few basic channels covering local news, weather, and sports with nothing more. Therefore, cable operators tiered the program selections according to their subscribers' viewing habits. Since all cable system programs were on the system, it was natural to use a filter installed at the service drop to prevent the undesired program bands to be fed to the subscribers' home. This was referred, in the industry, as negative trapping; that is, the unordered services were trapped out of the subscriber service drop.

With the arrival of the satellite system that made available premium (pay) channels to cable operators, the negative traps could prevent these channels getting into homes not subscribing to these channels. System audits could be made simply by passing the aerial plant taps and looking for the presence or absence of the traps. This method was easily defeated by subscribers getting up to the tap usually by use of a ladder and removing the trap. More determined cheaters replaced the trap filter with a look-alike device to fool the cable operator. Hence, the pilfering of cable services started and program security became an issue.

Today cable operators have developed various programs to control the theft of cable services. From negative signal-trapping methods, the positive trap method was developed. This method employed an interfering carrier system in which an interfering carrier signal was injected in the band of the signal to be protected. At the subscriber tap, a trap would filter out the interfering carrier, allowing the signal to enter the subscriber drop without the interfering signal so the subscriber could receive the premium program. This method meant that only premium (pay) program subscribers would need this trap. The ratio of premium subscribers to non-premium subscribers was an important factor for making the economic decision for the best method. In short, a system that does not have many pay program subscribers needs a greater number of negative traps than positive-type traps.

It must be remembered that the programming choices are the stock and trade of the cable television industry. In today's market where the computer Internet connection is a desired service, many telephone system service providers have difficulty in delivering large data files because of the limiting transfer speeds or low bit rates. A cable system's bandwidth can allow for faster downstream bit rates, but upstream ordering capabilities are in many cases not available. For cable systems operating in the present computer environment, the expansion toward two services is a must. Bidirectional plants with sufficient bandwidth are necessary for cable operators to become players in the telecommunications field.

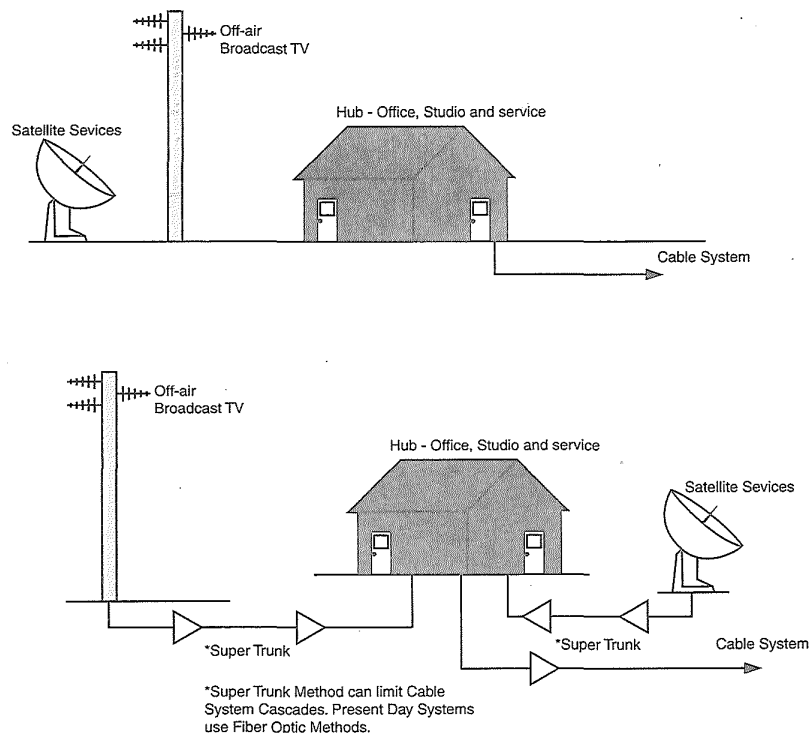
The Head-end

The cable system head-end is the source for all the programs offered on a system. It is also the main source of control, often referred to the root of the trunk/branch-tree network. From this point, signals are delivered to subscribers via the trunk/distribution cable system known as the limbs and branches of the tree network topology. The head-end system can vary from one central point to a system of other source points feeding a common source node. Head-end signal system networks can range from simple to several locations connected by a trunk cable system. Some head-end network topology is shown in Figure 2-5.

Antennas and Off-Air Reception

One very important source of signals most subscribers watch and depend on is the local television broadcast stations. These stations are the local

Figure 2-5
Examples of
head/end-hub
configuration



network affiliate in the standard VHF band plus the independents and the public broadcast stations. Local news, weather, and sports are usually favored programming. After all, cable television got its start carrying the off-air broadcast stations to distant areas or areas where the signal was of poor quality. Usually cable companies receive the off-air broadcast stations from tower-mounted antennas feeding the signal to amplifiers or signal processors in the head-end electronic equipment building. Usually this building was placed near the foot of the tower. An ideal situation would be to have the satellite receiving antennas and equipment at this location as well.

Antenna Types Log periodic antennas and Yagi antennas are the two most common types for VHF reception. Figure 2-6a-b shows these two types of antennas. The log periodic is a bit more broad-band and hence can be used for two or three adjacent channels, providing the stations are in the same pointing direction. This antenna has good gain, directivity, and high front-to-back ratio characteristics and is usually the antenna of choice for moderate to distant television stations.

For UHF TV station applications, the bow-tie corner reflector can be used for stations not too far away and for distant stations either the wire type or solid-aluminum parabolic antenna is usually the best choice. These antenna types are shown in Figure 2-7.

Placement on the antenna tower or mast is important and, unfortunately in many instances, is overlooked by some cable systems. The close

Figure 2-6a
Yagi pattern

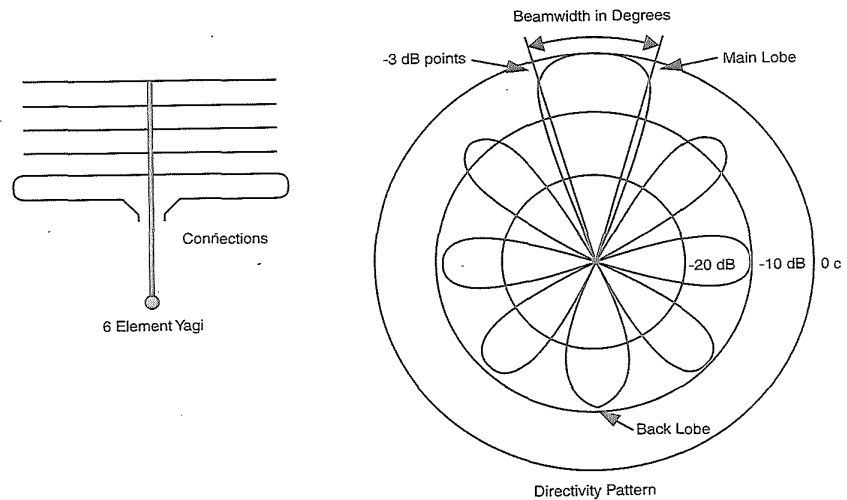
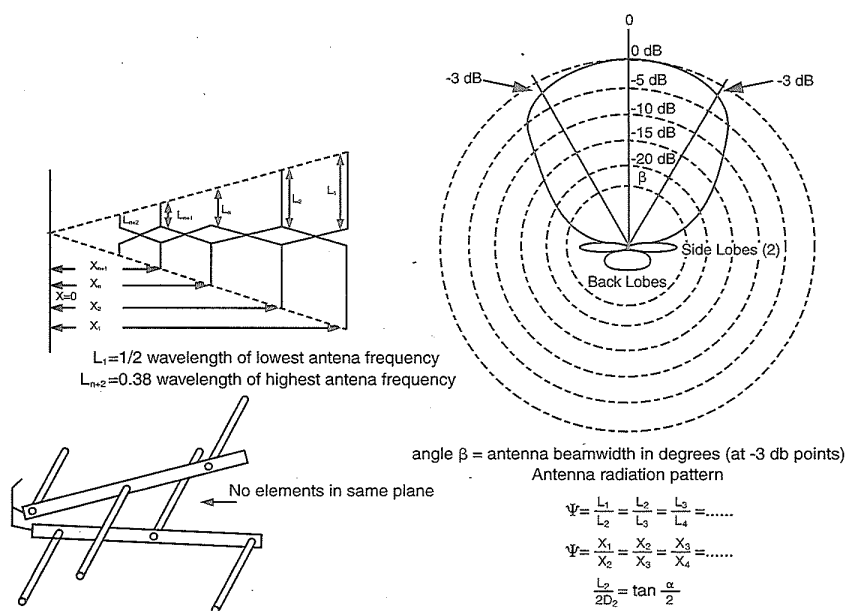
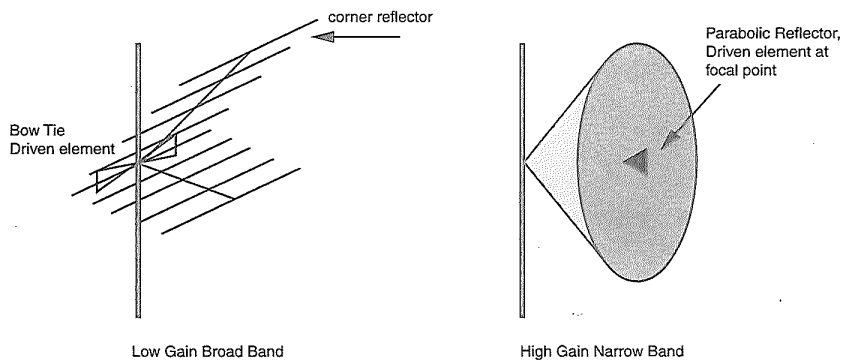


Figure 2-6b

Log periodic antenna

**Figure 2-7**

Corner reflector and parabolic antennas



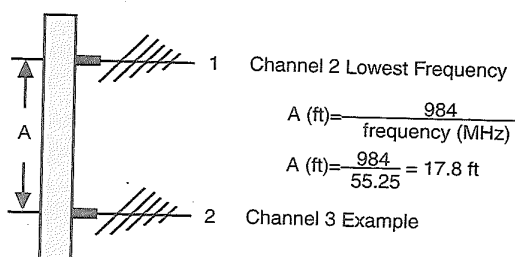
proximity of antennas can interfere with the antenna beam patterns of each, and proper spacing, depending on the wavelengths of the antennas, is required to overcome this problem.

Placement on Tower Placement on the tower between VHF antennas is often the main consideration. Since UHF stations operate at shorter wavelengths, the separation between antennas can be closer. Also the loca-

tion of antennas depends on the pointing direction. For example, antennas placed at directions on opposite tower legs can be spaced vertically closer. This case is shown in Figure 2-8.

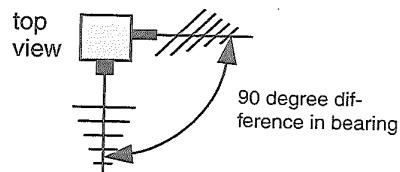
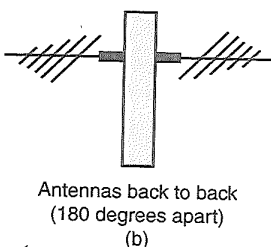
Notice that antennas pointing in a direction 180 degrees from each other can be placed on different tower legs at the same level. When working on the antenna placement problems on a tower, the result will be the necessary amount of tower height needed for the required antennas. Once this mea-

Figure 2-8
Antenna mounting
location on tower



1. The antenna for the weakest station should occupy the topmost section of the tower.
2. If the receiver signals are equal, place the highest frequency (smallest) on top so as not to weigh the top unnecessarily.
3. Follow the procedures outlined for proper minimum allowed spacing.

Vertical Separation of Antennas
(a)



$$A_{\min} = A \left(1 - \frac{0}{180} \right)$$

$$= 17.8 \left(1 - \frac{90}{180} \right)$$

$$= 17.8 \left(1 - \frac{1}{2} \right) = 17.8 \times \frac{1}{2}$$

$$= 8.9 \text{ ft (or } 1/2 \text{ what it was before)}$$

Antennas 90 degrees apart
(c)

surement is known, the next issue is the amount of added height needed for proper signal strength. The usual method involves an on-site signal survey, which involves some expense.

First and foremost is obtaining the broadcast station signal contour maps, which are often available from either the antenna manufacturers or from a consulting firm specializing in performing such on-site signal surveys. Data taken from these maps can tell whether a full signal survey is necessary. In many instances, the cable system technical staff can simply go to the site and erect a temporary wide-band rooftop antenna and take signal-level measurements and picture-quality measurements with a signal-level meter and a television set. If any interference is evident, further signal tests with a spectrum analyzer may be necessary.

Pre-amplification If some of the desired stations may be quite weak due to the distance from the station, a pre-amplifier may solve the problem. In some instances, the pre-amp can be placed in the head-end building before the signal processor, or if the signal is extremely weak, the pre-amp can be placed on the tower at the antenna. Tower-mounted pre-amps usually are fed their power through the coaxial cable download. Care must be taken to maintain good coaxial connections with no chance of moisture ingress so corrosion problems can be prevented. The signal-to-noise ratio is the most important parameter for the pre-amp placement problem and is shown in an example in Figure 2-9.

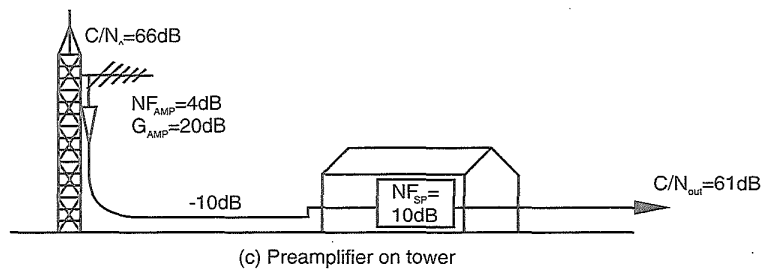
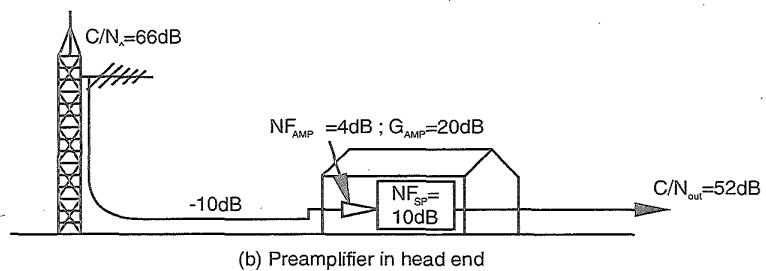
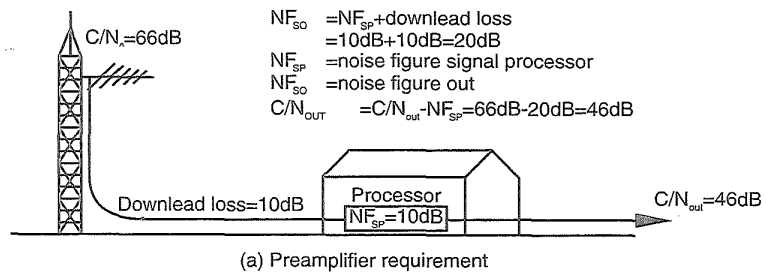
For UHF stations, the download loss can become a significant parameter for particularly tall towers or where the head-end off-air building is separated a long distance from the tower. If this loss is significant, a tower-mounted converter can be used that converts the UHF signal to a VHF signal, which now has a lower cable loss. Often these converters contain a pre-amp that improves the signal-to-noise ratio. An example comparing the results of the use of a converter and the results without one is shown in Figure 2-10.

Cable systems requiring tower-mounted converters and/or pre-amps are usually at remote areas far from the broadcast stations. For metropolitan cable systems, often a tall building's roof can be used to circumvent the multipath reception problem. For such systems, signal level is not a problem so small, more elementary antennas are sufficient. Again, an on-site signal survey will tell the story and indicate the needed equipment.

Tower Types Most cable systems use some form of tower or antenna mast to support the off-air antennas. Therefore, some space should be devoted to the discussion of towers and tower maintenance. Towers over the

Figure 2-9

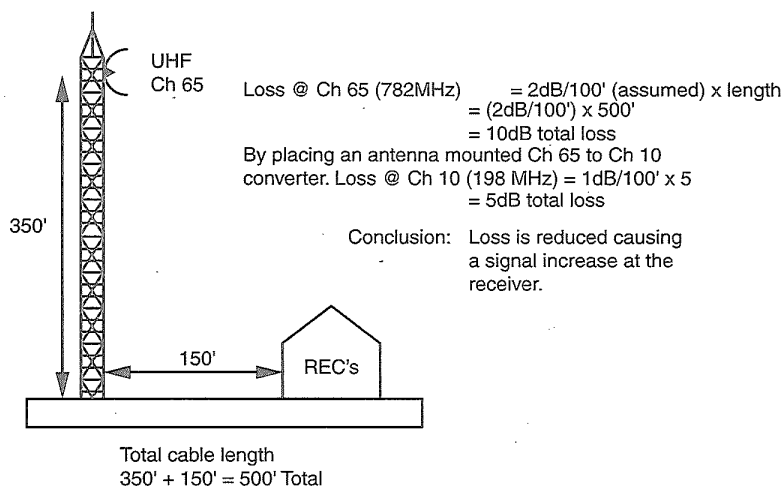
Pre-amp location at head end



usual 200-foot height are considered obstructions and are a hazard to airplane traffic. Proper application should be made to the obstruction department of the regional *Federal Aviation Administration* (FAA) office. Information pertaining to the location of the office can usually be found in the telephone book under U.S. Government or by calling the local regional airport. The FAA office will provide the necessary application forms and procedures to apply for permission to construct. Any required lighting and painting requirements will be specified by the FAA.

Figure 2-10

Tower mounted
amplifier converter
application and
signal level
comparison



Normally, towers over 200 feet and less than 300 feet usually require a flashing red beacon light at the top, a set of three fixed side lights at the halfway mark, and orange and white paint alternated at usually 20-foot intervals. Taller towers may require a flashing beacon at its center in addition to the top beacon. Also, two sets of fixed side lights between the flashing beacons are required at its center.

Towers fall into two main categories: self-supporting and guyed towers. Self-supporting towers are usually three-legged, but some older ones may be four-legged. They are generally more expensive but use less land than guyed towers. Large self-supporting towers are usually too expensive for most cable television applications. Guyed towers are more common for cable applications and range in height from 100 feet to 300 feet. Higher towers require more land for the guy wires and often use three inner guys and three outer guys. A comparison between the free-standing tower and a guyed tower is shown in Figure 2-11, showing the relationship between the height and land requirements.

Guyed towers are usually triangular and may have either a fixed based mount or a tapered based mount, as shown in Figure 2-12. The difference is in the distribution of the bending moments or forces on the tower legs. For shorter guyed triangular towers, the fixed base towers are often used. For solid rod towers, which are usually a lot heavier, use the tapered mount.

Manufacturers of towers usually have a customer engineering service department available to assist the customer in specifying an appropriate tower. Tower installation crews can often be arranged through the

Figure 2-11
Head-end towers

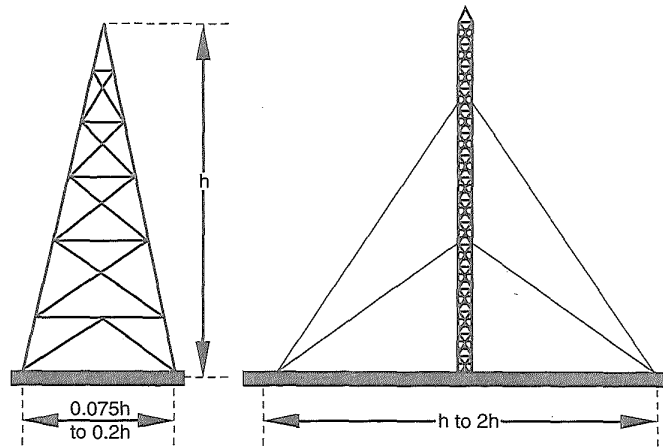
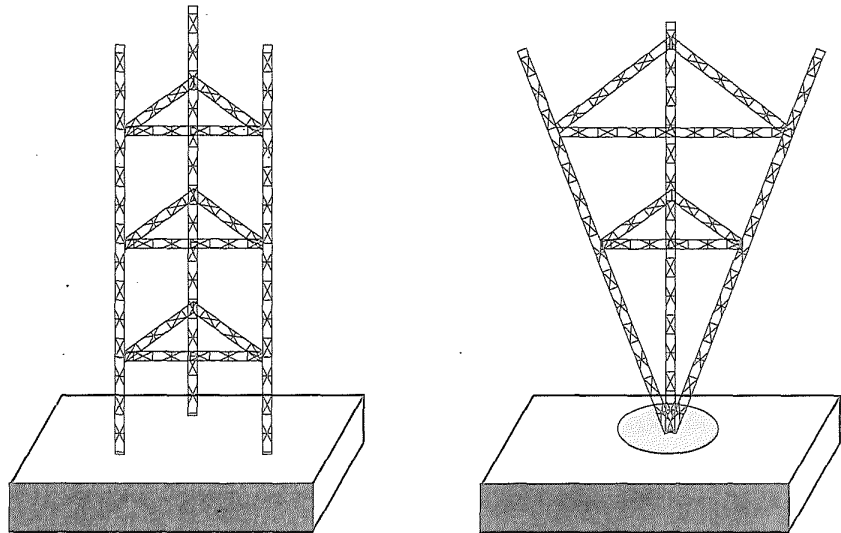


Figure 2-12
Tower base mounting



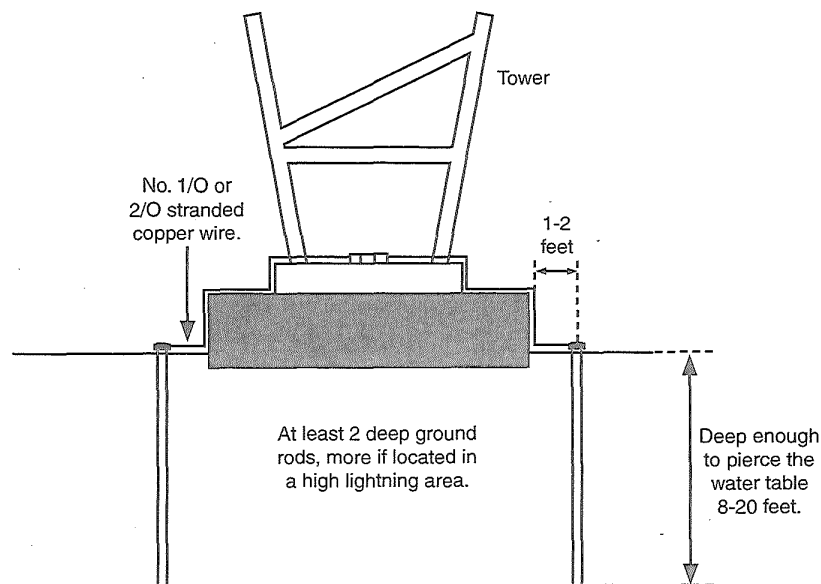
manufacturers. In many instances, a tower turnkey contract can be obtained that provides complete engineering, installation, grounding, lighting, and antenna installation services. Such a contract is often the best way to go for a cable system operator since most cable systems do not have a staff member trained in tower work.

Tower Grounding Methods Proper tower grounding is an important consideration in the control of lightning during a thunderstorm. After all, the tower is a big lightning rod itself. Some operators just ground the base of the tower to a system of ground rods. A base-grounding method is shown in Figure 2-13. In heavier lightning-prone areas, a sharp copper rod is mounted at the top of the tower and connects through heavy copper wire to the ground point at the base of the tower. Placing heavy copper strips in the concrete before the tower base is poured and then when the base has cured ties the four ends together. Placing the tower base on top usually provides a superior ground for the tower.

Testing the ground with an instrument known as a megger will indicate the effectiveness of the ground. If this is performed at the time of installation, subsequent measurements on a yearly basis will detect any deterioration of the tower ground system. If a tower requires lighting, a commercial electric service has to be connected all the way up the tower. Thus, a good and effective ground is necessary to protect the lighting system and any tower-mounted electronic devices such as pre-amps and converters.

Tower Lighting Tower lighting systems are usually available through the tower manufacturer. The flashing control system is usually mounted near the tower base on one leg of the tower and has a light-detecting cell

Figure 2-13
A typical tower
grounding method



that turns the light system on at dusk. Since the tower lights use considerable electricity, it is prudent to just turn them on at dusk and off at sun-up. The flashing mechanism is also mounted in the control box. Early flashing systems were electromechanical where a motor turned a crank that opened and closed the beacon switch. Most present-day systems use solid-state flashing technology.

A periodic inspection of the tower system should be performed on a seasonal basis (four times a year). Such an inspection should include the guying system, as well as the anchors and wire fastenings and grounding. Any loose clasps should be tightened and any observable rust should be coated with a protectant spray. The lighting system can be easily checked by placing a heavy work glove over the daylight-sensing element, thus turning on the beacons and side lights. Burned-out bulbs should be promptly replaced. Also the tower grounding system should be inspected and any observable corrosion treated. A record of these inspections should be kept in a tower maintenance file.

Head-end Electronic Equipment

Signal-processing systems for received off-air television signals have changed drastically and for the better throughout the years. Early systems simply used single-channel amplifiers operating with vacuum tubes as the gain element. With the development of transistors that exhibited high-frequency gain characteristics, the single-channel strip amplifiers greatly improved. The addition of automatic gain control was also a welcome addition. A major improvement in off-air signal-processing methods occurred with the development of the heterodyne signal processor. Signal processors today use *integrated circuit* (IC) technology and therefore are physically smaller, consume less power, and operate superbly.

Channel Strip Amplifier The strip single-channel amplifier with automatic gain is probably the lowest cost method to use for off-air signal processing. Essentially, this method couples a gain block with channel band-pass filters. At this point, the only signal amplified is the channel passed by the band-pass filter. The pass band is usually flat throughout the 6-MHz-wide television channel. The signal level is adjusted by a front panel control. Both the video and audio signals are passed through the amplifier, but an audio 4.5-MHz trap allows the sound carrier to be set to the usual 15 dB below video carrier level. This is necessary for consecutive channel operation and prevents the sound carrier level from interfering with the upper adjacent picture carrier.

Figure 2-14
Strip amplifier

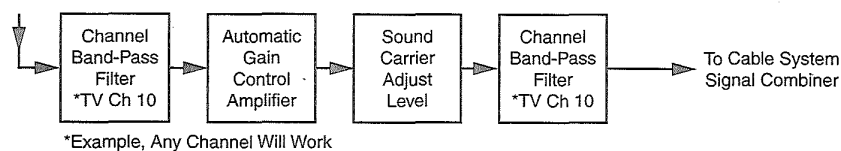
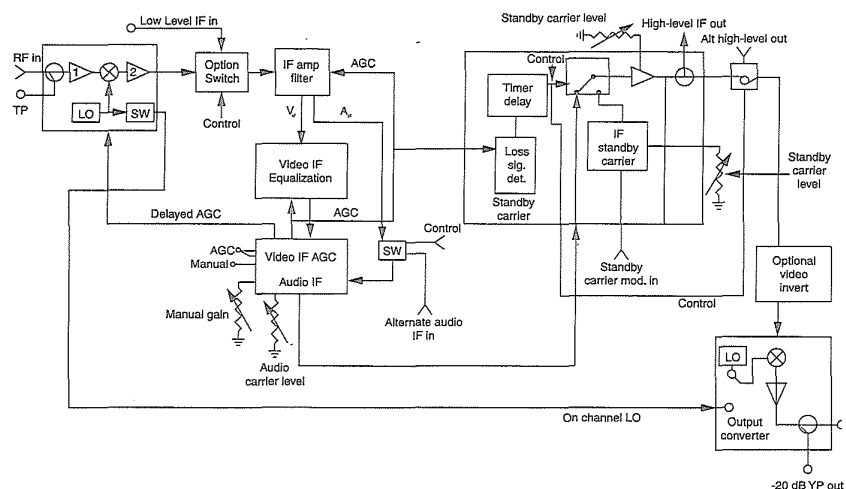


Figure 2-15
Signal processor
block diagram



Strip amplifiers often appeared in early systems and were often replaced later with the heterodyne signal processor. The strip amplifier method is shown in Figure 2-14.

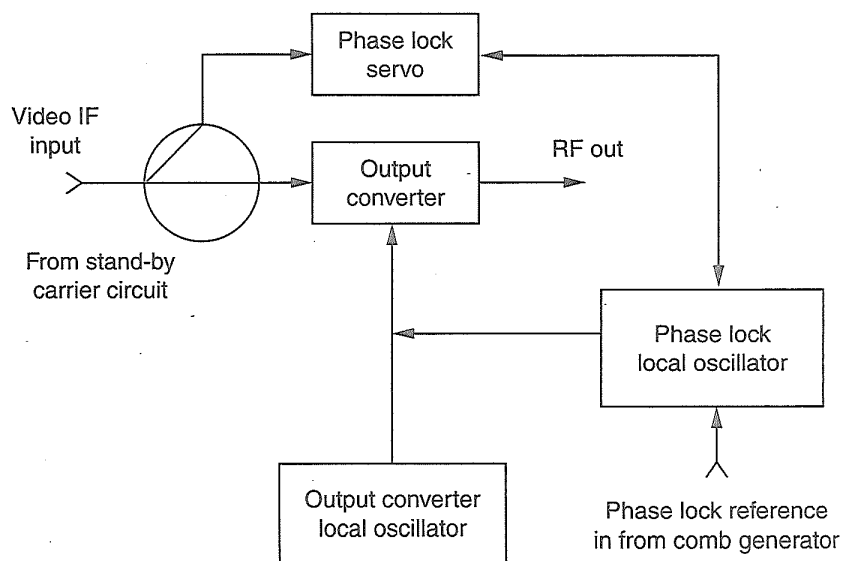
The Heterodyne Signal Processor Most systems use heterodyne signal processors for off-air television broadcast services. At one time, some cable systems opted for the Demod/Remod scheme, which required the received television station to be demodulated to base-band and remodulated back to either the same or a different cable channel. Such a system allowed local messages and or advertisements to be inserted at the video signal level. Also an *emergency alert system* (EAS) could be inserted in all the television channels. Voice or audio signal override could be easily introduced. Many manufacturers of present-day heterodyne signal processors offer many of the same features as the Demod/Remod method, only signal switching is done at IF. A block diagram of a heterodyne signal processor is shown in Figure 2-15.

This type of processor has many desirable features that enable many options for the operator. Probably the most desirable feature is the stand-by

carrier. If, for any reason, the input signal is lost, either because the station went off the air or a problem occurred with the receiving antenna, a substitute carrier at the correct level would be introduced into the cable system. This replacement signal would continue until the off-air signal was returned to the input of the processor and this standby carrier could be modulated by a replacement video signal. Such a signal could be a simple "please stand by" message. If the channel happened to be used as a pilot carrier on the system, a properly level-adjusted stand-by carrier is absolutely required in order to maintain the cable system automatic level and slope system.

Another feature that is often used is alternate IF switching, which allows another signal source to be introduced at the IF frequency. This feature was developed for cable systems that were required to drop an off-air channel that contained the same program as one of the must-carry broadcast stations. Such a condition is referred to as non-duplication or simply non-dupe switching. Cable systems that use the off-air method of receiving broadcast programs use heterodyne signal processors. Several manufacturers make some superb signal-processing equipment that also features the capability of phase-locking to a comb generator. Such phase-locking is necessary for either an *incrementally related carrier* (IRC) system or a *harmonically related carrier* (HRC) controlled systems. A block diagram of the processor phase lock loop is shown in Figure 2-16.

Figure 2-16
Signal processor
phase-lock circuit

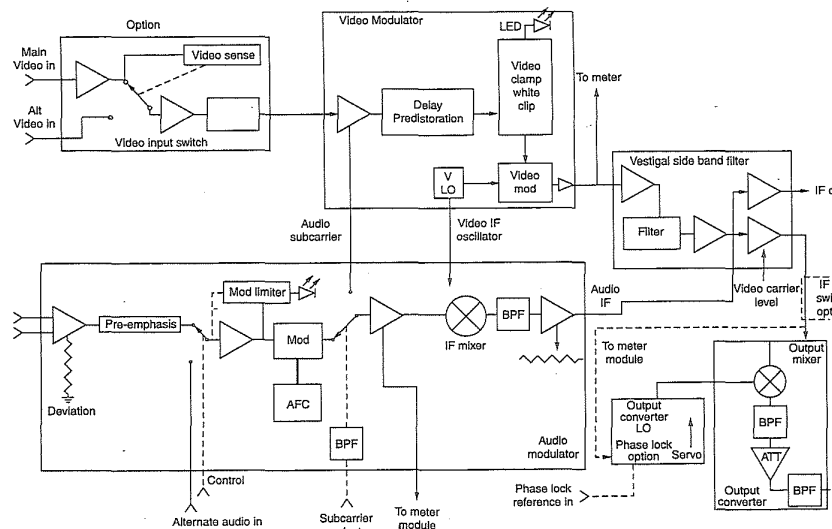


The Television Modulator A television modulator, as used by the CATV operator, is in essence a miniature television broadcast transmitter. The signal-processing stages have to perform with the same specifications as a broadcast television station. The block diagram for a present-day television modulator is shown in Figure 2-17. Elementary television modulators are found in such devices as VCRs where the recorded video/audio signal is played and sent to a modulation circuit that transforms the video/audio signal to a standard TV channel, typically channel 3 or 4. The modulator for cable television use is vastly different from this type of device.

Referring to Figure 2-17, notice that there are two video inputs and two audio inputs. One is the main channel and the other is the alternate channel, which is controlled by a selector switch. The switch can also have the option to switch to the alternate source upon loss of the main input video signal. The alternate source can be a simple "please stand by" or some other appropriate message. Just about any signal can either be introduced or outputted for a variety of applications. Options provide for full video/audio metering and system phase-locking capability.

Manufacturers of head-end equipment offer cable systems a variety of television modulators from extremely compact types to larger ones containing a large selection of options. Some modulators have a selectable or tunable output and can be considered as a sort of universal device. Often these modulators do not have a selectable band-pass output filter and can

Figure 2-17
Television modulator

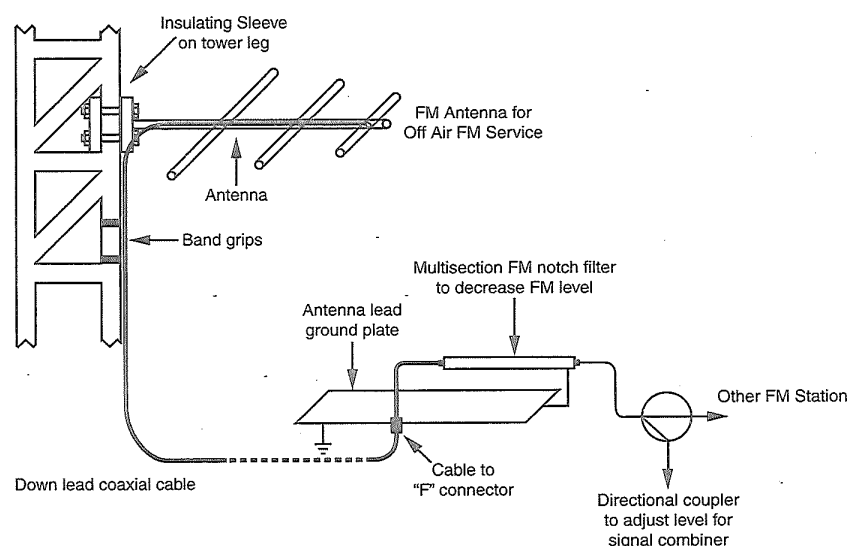


add broad-band noise into the channel-combining network. A more prudent approach is to use normal single-channel output converters with band-pass filtering for all channels requiring a modulator. The tunable type modulators can be used as spares. In general, the use of modulators is for satellite-originated programming and locally generated program channels.

Signal Combining and Filtering The next process in assembling the television channel line-up is the combining of all the program channels into one terminal used to drive the coaxial cable network. Care must be taken at this point to not inject any added noise or unwanted signals into the system. In some instances, through either local ordinances or for economic reasons, the cable television system may use an active AM or FM tower for its off-air antenna system. Thus, the problems of preventing the transmitted station from entering the cable system can be extremely difficult. An example of such a problem is shown in Figure 2-18, but the solution may not be as simple as that shown. Situations such as this should be avoided if at all possible. A spectrum analyzer measurement of the whole cable spectrum at the combining point will show all the video and audio carrier levels as well as any extraneous signals.

The combining network can be made from a tree of 75-ohm two-port splitters that is used as a combiner or as a series of directional couplers. The tree method contains the least loss and therefore the signals to be combined

Figure 2-18
FM antenna for
broadband FM
service on cables.
The antennas are
mounted on an FM
transmitting tower



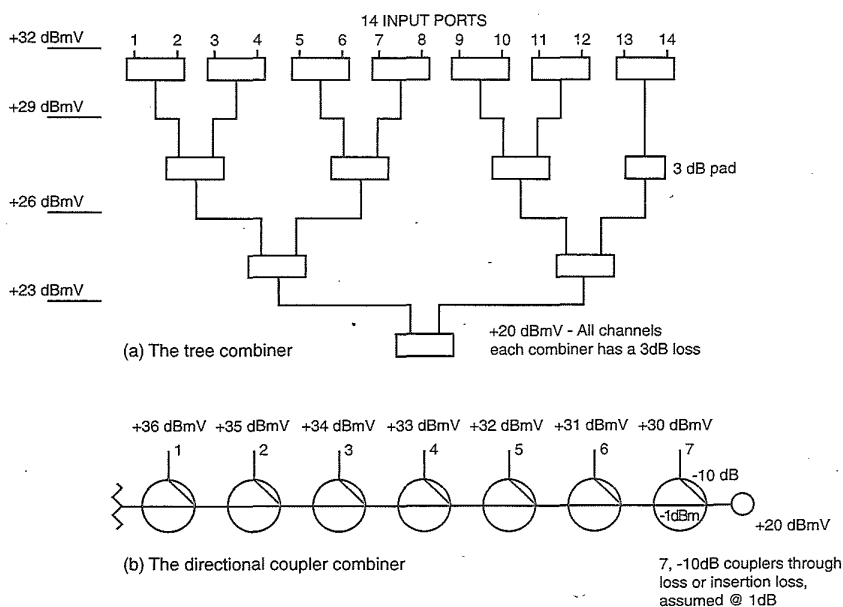
do not have to run at such high levels. Manufacturers of head-end equipment usually have directional couplers for combining networks in their product lines. This is the more usual type of network used. Ideally, each channel should have an output band-pass filter. This prevents any extraneous broad-band noise from entering the cable system. The two mentioned types of combining methods are shown in Figure 2-19.

Head-end Powering and Monitoring

Cable television head-ends usually are operated by commercial power brought to the site by aerial or underground means. In the case where there is a commercial power failure, some means of backup power is recommended. Current cable systems should attempt to operate with the same reliability figures as the telephone system. This is a must-do if cable operators are going to compete in the business of providing voice, data, and video communications. Since signal reliability is an issue, head-end signal monitoring also should be considered.

Stand-by Power Stand-by powering of head-end equipment falls into two basic categories: an engine-generator set and a battery back-up set. The

Figure 2-19
Signal combining
network types



battery back-up set can be as exotic as an *uninterruptible power supply* (UPS). Since most head-ends have some kind of alarm system, such as for unauthorized intrusion, fire and/or smoke, these could also alert the loss of commercial power. Service personnel could then go to the head-end site to monitor the situation. The most common type of head-end emergency power is the engine generator set, simply because it can usually provide 100 percent of the usual power load that includes air conditioning and tower lights in addition to the normal electronic load. The engines are usually reciprocating multicylinder engines that operate on a variety of fuels. Large stand-by plants often use diesel fuel, while some use gasoline, propane, or piped-in natural gas as a fuel.

Several manufacturers of engine-driven stand-by power plants offer equipment in a broad range of powers. Battery-powered back-up systems usually provide enough power covering anywhere from a one- to two-hour off period. For engine-driven emergency power systems, an automatic program change-over switch is the method of choice. This device starts the engine, tests the voltage, and transfers the power. Upon return of commercial power, as sensed by the switch, the power transfer is made back to commercial power and the engine is shut down.

An engine-run hour meter records the amount of time the engine was in operation. This data should be recorded in the plant maintenance file. Some emergency electric plant controllers have a weekly or monthly cycle period where the engine starts and runs for a predetermined period and then shuts down. This so-called exercise cycle may or may not actually transfer the electrical load.

Battery back-up power systems usually do not have an exercise cycle. The condition of the battery pack should be checked visually as well as electrically, and the condition of the charge should be recorded in the system maintenance files. Most uninterruptible power back-up systems either remain online, providing power while simultaneously being charged, or are switched online at commercial power outages. At the return of commercial power service, these systems transfer off-line and resume charging. As yet, most manufacturers of head-end electronic devices do not offer back-up power options on a device-by-device basis. Since many computer systems use such back-up power supplies, it is most likely this method will be used in hubs and head-ends.

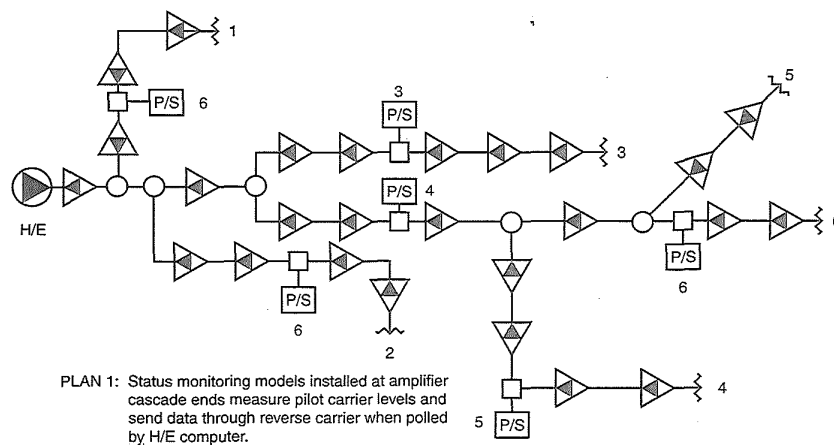
Signal Monitoring Manual or Automatic Signal reliability is now of extreme importance in many modern systems, so some means of signal monitoring and testing should be used. The testing/monitoring program can be done manually by test technicians and monitoring data is recorded in a site

logbook. The advantage of such a program is that if a problem is observed it can be corrected at once. However, this method, being labor-intensive, is the most expensive. An automatic method involves the installation of programmed instruments to make periodic measurements in a predetermined sequence. The results can be converted to digital data and recorded on a floppy disk. This system can also be interrupted manually at the control computer terminal for a visual test of the system's operating parameters.

If one or more head-end sites are monitored in this fashion, a central office-monitoring computer can be operated via a data communication channel through the cable system. Such an interconnected system is shown in Figure 2-20. Each site can in turn be interrogated for its measurement data by the control computer through the usual data-type modems. Data found to be faulty by the monitoring computer can signal an alarm so technical personnel can respond and correct the problem. Carefully selecting the alarm threshold can facilitate heading off problems before an actual signal outage occurs.

Grounding and Bonding An important concern for the head-end electronic equipment is that grounding and bonding be done properly. For most head-end layouts, electronic devices such as signal processors, modulators, satellite receivers, and ad-insertion equipment are mounted in metal racks. In some instances, open-standard, 19-inch telephone-type racks are used, and for more upscale head-ends, the equipment is mounted in enclosed rack cabinets. The metal racks should be connected together with either heavy

Figure 2-20
Status monitoring of
end levels and/or
power supply status



PLAN 1: Status monitoring models installed at amplifier cascade ends measure pilot carrier levels and send data through reverse carrier when polled by H/E computer.

PLAN 2: Test status of each power supply when polled by H/E computer.

PLAN 1 and PLAN 2 could both be used.

(1/0 or 2/0) copper wire, bus bars, or braids and then connected to a grounded electrode. This ground point should be the same electrode as the power system ground. Now no fault currents can set up through several paths to ground. The ground method should provide less than 25 ohms to the ground, as tested with a megger or milliohm meter.

Some head-ends operating near television or FM/AM radio-transmitting facilities have to use RF chokes and bypass capacitors at the power service panel to prevent RF ingress of unwanted signals entering the cable system. Cables entering the electronic equipment building from the antenna, often referred to as downleads, have to be connected to a heavy aluminum plate grounded at the head-end common ground point. The heavy, usually half-inch solid aluminum sheath system cable used as a downlead is connectorized to this panel through half-inch "F" connectors. Now simple RG-6 cable connects to the equipment in the racks.

Since most head-ends use towers for the off-air receiving antennas, lightning can again be a problem. Proper grounding can help prevent the direct effects of a lightning strike, but large spikes of voltage can be induced into the power lines, causing power surges of significant magnitude. Such power surges can cause blown fuses or equipment failure of a significant nature. A good idea is to have a surge suppression system in place. Simple surge suppressors can be used at each device plug, but a larger unit mounted in or at the power distribution panel saves a lot of clutter and is quite effective. Several manufacturers make panel-mounted surge suppressors, offering various features, shapes, and sizes. Basically, the surge suppressor has to pass the load, removing any voltage spikes and delivering smooth power free of electrical transients to the equipment. By now, it should be evident that there are a large number of considerations when planning a head-end.

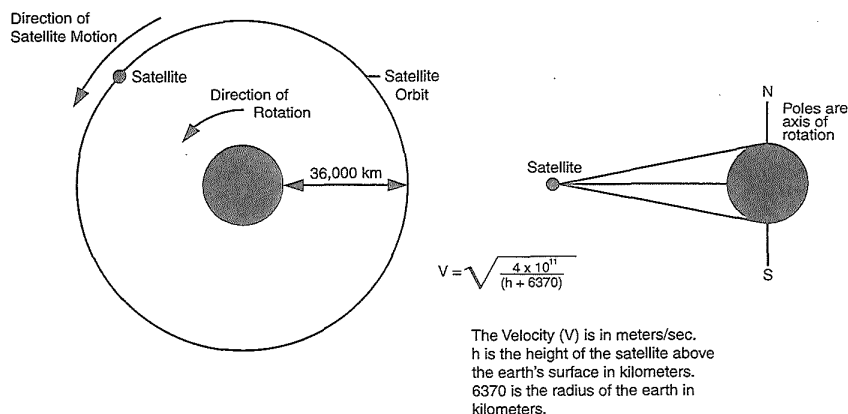
Satellite Systems

Some of the people who started cable systems back in the 1950s and 1960s recall the days when there were no satellite systems operating. Cable television systems were simply a means used to deliver greatly improved television broadcast signals to subscribers, a true community antenna television system. Many early systems had unused bandwidth or channel space. When satellite systems were developed to the point where more programming became available to the cable operator, more bandwidth was needed to carry the added services. The axiom that said, "If you have more to sell, you sell more," became an important rule for cable operators. Communication satellites are very important to the telecommunication industry and affect many users around the world.

Geostationary Satellites Of the many satellite systems in place covering the Western hemisphere, the geostationary ones are the important ones to the cable television industry. Basically, a geostationary satellite is in a circular, equatorial orbit. Figure 2-21 shows the geostationary satellite concept. Notice that the usual orbit direction is the same as the earth's rotation and the height above the earth surface is about 36,000 kilometers (21,600 statute miles). One such satellite can cover better than two-thirds of the earth's surface. Satellites that orbit the earth have to conform to the velocity equation given in Figure 2-21. Satellites that are in a geostationary orbit have the same angular velocity as that of the earth. Therefore, the circumference of the orbit divided into the orbit speed as calculated by the equation will give the period of the orbit as 24 hours. This is the same as the earth's period of rotation.

When planning a satellite receiving system for a cable system, a frequency coordination study should be made as soon as the desired satellite channels have been determined. This study provides information on the amount of expected or possible interference from any other surrounding microwave communication facilities. Microwave-common carriers, such as any of the local telephone systems, use the same frequency bands as some of the satellite systems. This study is a service offered by several companies that has amassed a database of frequencies and their propagation paths. If this study indicates possible interference from any local sources, an onsite measurement may be necessary to determine if the interference is of a sufficient level to cause a problem. A possible cure is to erect a conductive shield near the receiver antenna or to construct an artificial hill in the direction of interference. Some manufacturers make a shield ring around

Figure 2-21
Geostationary satellite orbit



the parabolic antenna, which reduces the effective side lobe pattern of the antenna. If no cures are feasible, the receiving site may have to be relocated to a place that has no interference problems. Now it may be necessary to super-trunk the signals to the hub head-end site or main signal distribution location. All of this investigative work should be satisfactorily completed before any construction begins.

Siting the Earth Station One of the important tasks is to make sure the parabolic receiving antenna can get a clear path to the satellite. No trees or buildings can obstruct the path. In many instances, some trees have to be removed so the path from antenna to satellite is clear. In order to do this, the azimuth and elevation look angles have to be determined.

Several pieces of information have to be assembled in order to establish the look angles for the antenna. The satellite longitude has to be known, but notice there is no latitude given because zero latitude is the equator. Next, the receiving site latitude and longitude have to be determined to an accuracy of the nearest hundredth of a degree. A U.S. coast and geodetic survey map of the 7.5-minute type is adequate to determine the site latitude/longitude coordinates. Often sporting goods stores have these maps for sale. A local civil engineering/surveying office will be able to determine the site coordinates. A GPS hand-held satellite global positioning receiver operating in the differential mode can provide coordinate information to a sufficient accuracy. Such instruments are available in sporting goods stores for a few hundred dollars. In most cases, the prospective site coordinates are needed for the frequency coordination study. The calculation for the azimuth angle in degrees from true north and the elevation angle in degrees from level ground can be calculated. The method and formulas with a worked-out example are shown in Example 2-1.

Once the elevation angle is found, the slant range or simply the distance from the receiving antenna site to the satellite can be determined, as shown in Example 2-2. This distance is used to calculate the signal path loss.

For various satellites, the satellite communication operators have a map with the projected *effective isotropic radiated power* (EIRP) contour lines appearing on it. For receiving sites found on the map, the EIRP can be determined. An example of such a map is shown in Figure 2-22. The calculation for the expected carrier-to-noise level at the receiver pre-amplifier input can now be made and an example is shown in Example 2-3. If a better C/N ratio is required, a larger antenna will be required.

Satellite Receiving Antennas Once the calculations are made, the receiving antenna specifications will be known. Now the decision can be

Example 2-1Satellite pointing
angles

The formulas are as follows:

Antenna azimuth angle (degrees) =

$$180 + \tan^{-1} \left(\frac{\tan D}{\sin X} \right) \text{ (from true north)}$$

Antenna elevation angle (degrees) =

$$\left(\frac{\{\cos D \times \cos X\} - 0.15126}{\sqrt{\{\sin D\}^2 + \{\cos D \times \sin X\}^2}} \right)$$

where X = earth station site latitude

Y = earth station site longitude

Z = satellite longitude

D = Z - Y

Example

Earth station site latitude 41° 38' 11.0" N

Earth station site longitude 70° 27' 42.0" W

Satellite galaxy I longitude 93.5° W

Solution: Convert latitude and longitude of Earth station site to decimal degrees.

Earth station latitude		Earth station longitude	
41° =	41.0000	70° =	72.0000
38' = 38/60 =	0.6333	27' = 27/60 =	0.4500
11.0" = 11/3600 =	0.0031	42" = 42/3600 =	0.0117
	41.6364 = 41.64		70.4617 = 70.46

where X = 41.64°

Y = 70.46°

Z = 93.5°

D = 93.5 - 70.46 = 23.04°

$$\begin{aligned} \text{Azimuth angle (degrees)} &= 180 + \tan^{-1} \left(\frac{\tan D}{\sin X} \right) \\ &= 180 + \tan^{-1} \left(\frac{\tan 23.04^\circ}{\sin 41.64^\circ} \right) = 180 + \tan^{-1} \left(\frac{0.425}{0.66} \right) \\ &= 180 + \tan^{-1}(0.644) \\ 180 + 32.8^\circ &= 212^\circ \text{ from true north} \end{aligned}$$

$$\begin{aligned} \text{Elevation angle (degrees)} &= \tan^{-1} \left(\frac{\{\cos D \times \cos X\} - 0.15126}{\sqrt{\{\sin D\}^2 + \{\cos D \times \sin X\}^2}} \right) \\ &= \tan^{-1} \left(\frac{\{\cos 23.04 \times \cos 41.64\} - 0.15126}{\sqrt{\{\sin 23.04\}^2 + \{\cos D \times \sin X\}^2}} \right) \\ &= \tan^{-1} \left(\frac{\{0.920 \times 0.747\} - 0.15126}{\sqrt{\{0.391\}^2 + \{0.920 \times 0.664\}^2}} \right) \\ &= \tan^{-1} \left(\frac{0.6872 - 0.15126}{\sqrt{0.153 + 0.373}} \right) \\ &= \tan^{-1} \left(\frac{0.5359}{0.723} \right) = \tan^{-1}(0.7389) = 36.5^\circ \end{aligned}$$

Example 2-2

Calculation of the
distance from the
receiving antenna site
to the satellite

The distance from a point on Earth to a Satellite
can be calculated using the following formula:

$$d = \sqrt{[(r + h)^2 - (r(\cos\theta))^2]} - r(\sin\theta)$$

d = distance to the satellite in km

r = radius of the earth = 6370 km

h = height above satellite above equator = 35780 km

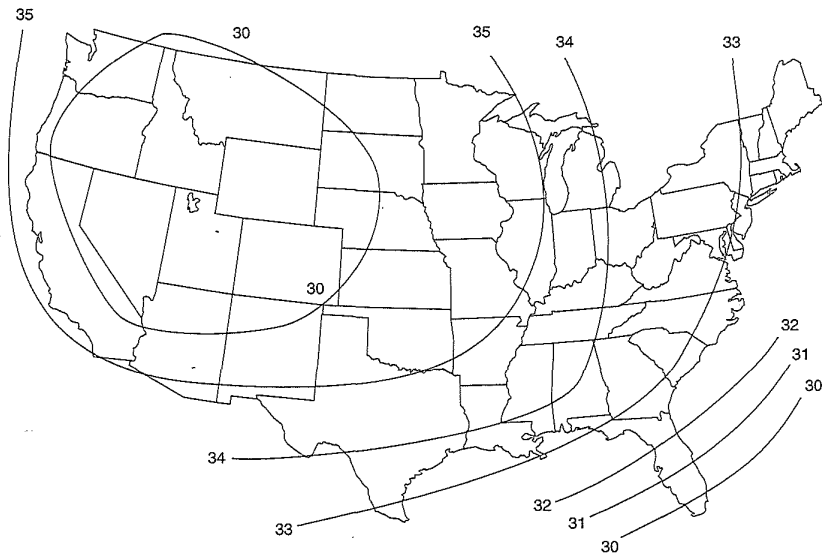
θ = elevation angle in degrees

Example: $\theta = 36.5^\circ$

$$\begin{aligned} d &= \sqrt{(42.15 \times 10^3)^2 - ((6.37 \times 10^3)(\cos 36.5^\circ))^2} - (6.37 \times 10^3)(\sin 36.5^\circ) \\ &= \sqrt{1806 \times 10^6 - (5.12 \times 10^3)^2} - 3.79 \times 10^3 \\ &= \sqrt{1806 \times 10^6 - 26.2 \times 10^6} - 3.79 \times 10^3 \\ &= \sqrt{1780 \times 10^6} - 3.79 \times 10^3 \\ &= 42.2 \times 10^3 - 3.79 \times 10^3 = 38.4 \times 10^3 \text{ km} \\ &= 38400 \text{ km} \end{aligned}$$

Figure 2-22

Calculation of the
distance from the
receiving antenna site
to the satellite



Example 2-3
Calculation of
path loss

To calculate the path between a satellite and a receiving site on earth may be calculated using the following procedure:

$$L_{\text{path}}(\text{dB}) = 32.44 + 20\log d_{(\text{km})} + 20\log f_{(\text{MHz})}$$

Example: for a frequency of 4 GHz (4000 MHz)
and where $d = 38400$ km.

$$\begin{aligned} L_{\text{path}}(\text{dB}) &= 32.44 + 20\log 38400 + 20\log 4000 \\ &= 32.44 + 20\log 3.84 + 80 \text{ dB} + 20\log 4 + 60 \text{ dB} \\ &= 32.44 + 11.69 + 80 \text{ dB} + 12 + 60 \end{aligned}$$

$$\text{Path loss} = 196 \text{ dB}$$

made as to the antenna size, the low noise block-down converter, and the types of feed-mount and lead-in cable. Several types of antennas can be fitted with feed mounts covering several satellites depending on their spacing in the satellite arc. For certain applications, five- and six-meter antennas can be fitted to cover three different fairly closely spaced satellites. Since adjacent satellite channels are transmitted alternately polarized (odd-numbered channels horizontally polarized with even-numbered channels vertically polarized), the frequency difference between adjacent channels and this polarization difference prevents any adjacent channel interference. Table 2-1 lists some commonly used C-Band channel information.

Satellites with polarization listed in Column A are GE Satcom C3, C4, and Hughes Galaxy IX.

Satellites with polarization listed in Column B are Hughes Galaxy IV, V, VI, VII, I-R, G.E. Satcom C1, and G.E. American GE-1.

Satellite receiving antennas have been fitted with the required vertically and horizontally polarized feeds with a low noise block-down converter connected to each one. The converter performs two basic functions. The first is to amplify the weak microwave signal and the second is to convert the

Table 2-1C-Band Satellite
Channel
Information

Sat. Ch.	Down Link MHz	Down Link Polarization	
		A	B
1	3720	V	H
2	3740	H	V
3	3760	V	H
4	3780	H	V
5	3800	V	H
6	3820	H	V
7	3840	V	H
8	3860	H	V
9	3880	V	H
10	3900	H	V
11	3920	V	H
12	3940	H	V
13	3960	V	H
14	3980	H	V
15	4000	V	H
16	4020	H	V
17	4040	V	H
18	4060	H	V
19	4080	V	H
20	4100	H	V
21	4120	V	H
22	4140	H	V
23	4160	V	H
24	4180	H	V

signals to a lower frequency. Converting to a lower frequency results in lower cable loss and therefore a less attenuated signal at the receiver. This method is shown in Figure 2-23 and is the most commonly used method.

Figure 2-23
Satellite antenna
block converter
configuration

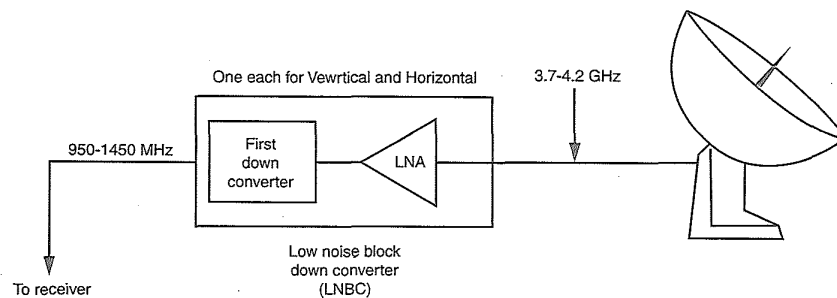


Table 2-2
C-Band to L-Band
Conversion

Transponder Number	C- Band Freq. MHz	L-Band Freq. MHz	Transponder Number	C- Band Freq. MHz	L-Band Freq. MHz
1	3720	1430	13	3960	1190
2	3740	1410	14	3980	1170
3	3760	1390	15	4000	1150
4	3780	1370	16	4020	1130
5	3800	1350	17	4040	1110
6	3820	1330	18	4060	1090
7	3840	1310	19	4080	1070
8	3860	1290	20	4100	1050
9	3880	1270	21	4120	1030
10	3900	1250	22	4140	1010
11	3920	1230	23	4160	990
12	3940	1210	24	4180	970

Satellite Receivers The receiver takes the converted C-band signals and produces a base-band descrambled signal. Many manufacturers provide what is known in the industry as an IRD (integrated receiver descrambler) satellite receiver. The receiver descrambler circuits are integrated into one package, thus conserving rack space in often crowded electronic equipment bays in larger head-ends. Table 2-2 shows a listing of C-band channel frequencies to their down-converted values. Notice that the low-frequency

C-band signals are converted to high-band frequency signals. This is due to the heterodyne frequency conversion process.

The L-band receivers on the market today have the C-band channel number indicated on the front panel, making the frequency values superfluous. An L-band receiver is shown in Figure 2-24.

Pay (Premium) TV Systems Much of the programming on satellite channels is scrambled and/or encrypted using several methods. The *General Instrument Corporation* (GI) developed the earlier type called Videocipher II, which was upgraded to Videocipher II+. Later methods that were developed and used by GI are DCI, DCII, DCII MCPC, and DCII SCPC. Scientific Atlanta Corporation has a series that is available to program suppliers called Pwrvu, Pwrvu MCPC, and Pwrvu SCPC. The purpose of using any of these methods of encoding is to prevent the unauthorized use of the programming material. The key for decoding is contained in the authorized equipment in the cable system head-end. The cable operator can then rescramble in the format compatible with the system's subscriber converter box.

A general observation might raise the question, if the signal is already scrambled, why descramble and then rescramble? The obvious answer depends on who is doing the scrambling or protecting the program service. Since passing the signal flow through more circuits adds noise or distortion,

Figure 2-24
Base band
output signals

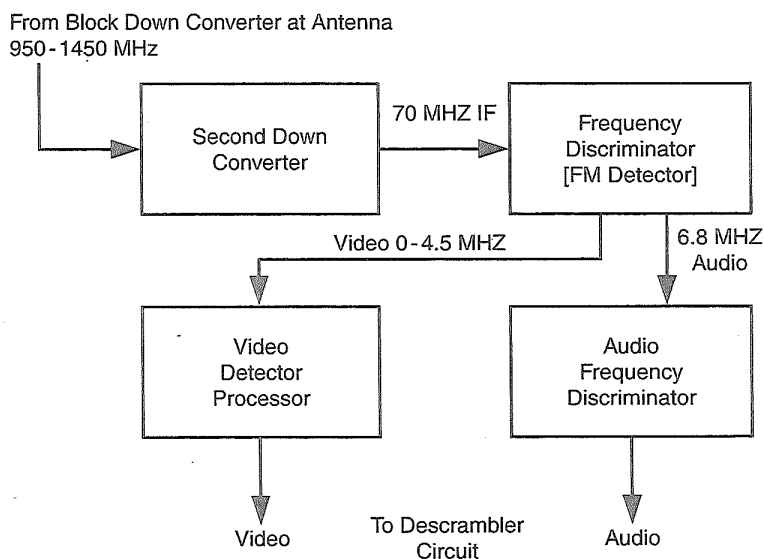
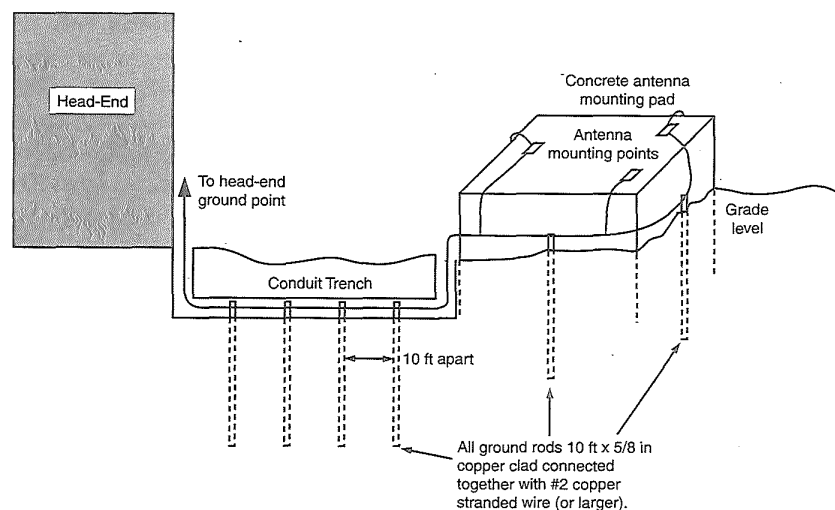


Figure 2-25
Satellite antenna
mounting platform
and grounding
system



possibly a better arrangement would be to pass the scrambled signal through the cable system to the subscriber's set-top box, where the signal is programmed to decode or unscramble. Doing it this way, the program supplier knows the cable company that is providing the service to the subscriber.

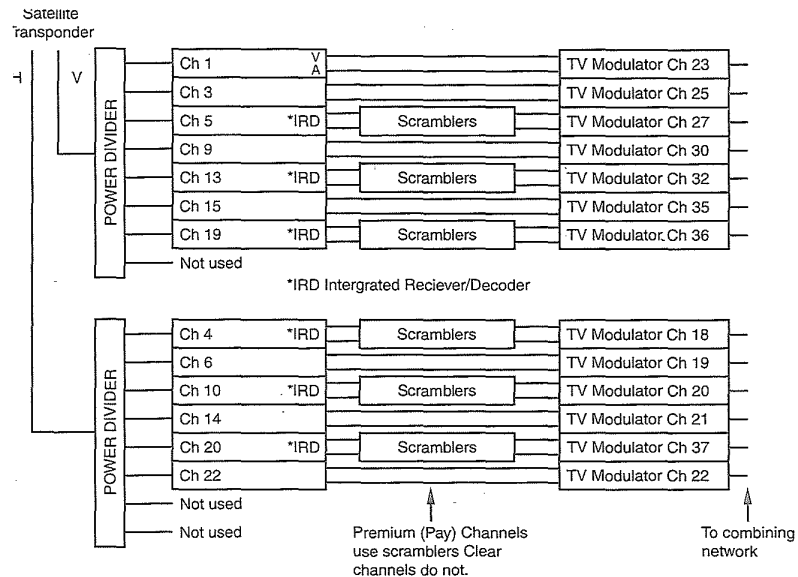
Grounding the earth-station antennas is also important in order to protect the sensitive LNBC equipment from the effects of lightning. Such a grounding plan is shown in Figure 2-25.

Satellite Signal Processing At the master head-end site, the satellite-received signals are either sent clear as part of a basic program package or are rescrambled as a premium or pay channel. All satellite channels are modulated on a cable system channel and are combined with the off-air broadcast stations plus any of the locally generated channels. In general, locally generated programs are the local television studio-originated signals, a character generator with the listing of the programs (program guide), and a character generator with lost-and-found column news announcements.

A block diagram showing the device interconnections for the processing of satellite program signals is shown in Figure 2-26. As suspected, many options and choices are available within the methods of interconnecting the equipment required to assemble the program line-up. Whatever the choice, the signal quality must always be preserved simply because it can never be better at the head-end. Once the signal enters the cable system, it is naturally degraded and much now depends on the cable system design.

Figure 2-26

13 channels from one satellite transponder, 6 pay channels re-scrambled and 5 clear channels



The Cable Distribution Plant

The coaxial cable system design consists of the trunk and distribution of coaxial cable sections of cascaded amplifiers. As mentioned before, simpler elementary systems of earlier designs consisted of single cable-connected amplifier cascades. No differences were made between trunk and feeder cables. It was soon determined that the trunk cable cascade should be the signal transportation medium and should just supply the signal to the feeder cable system containing subscriber taps and distribution type (line extender) amplifiers. This method extended the signal the greatest physical distance from the head-end and became known as the trunk-feeder system, or rather simply the trunk/branch method.

The Trunk-feeder System

The feeder-trunk method became the most accepted type of cable system design, known as the bread and butter of system architecture. System design and layout was often done manually on a drafting table, overlaying the design on a series of street maps. Often maps can be obtained from several possible sources, such as:

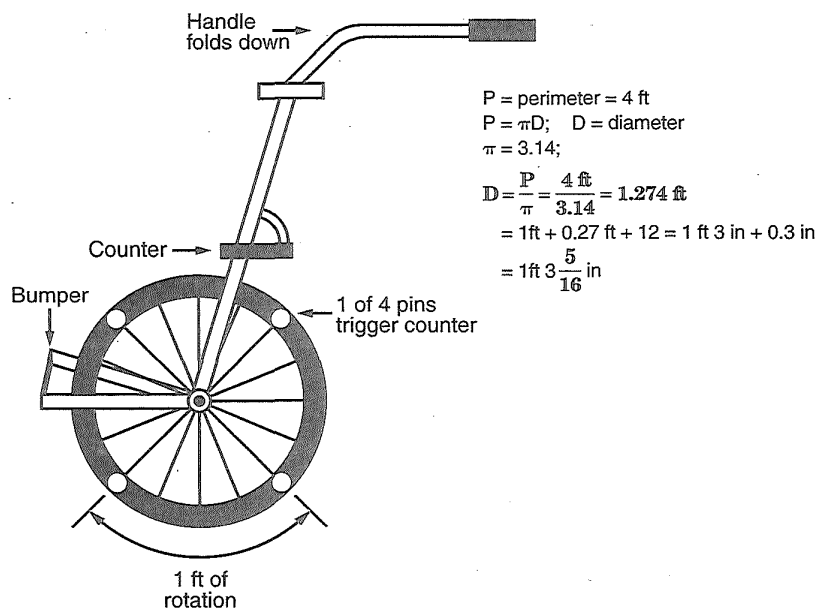
1. The local telephone or power company
2. A local land surveyor/civil engineer
3. The local town or city department of public utilities
4. U.S. Coast and Geological Survey maps

Many utility companies also offer their maps on either floppy disk or CD-ROM. Once maps are obtained, then strand-mapping can commence.

Since maps may not contain any late changes, a measurement using a measuring wheel or a surveyor's transit and stadia rod to measure the distance between utility poles may be necessary. If utility poles are not going to be used, then a wheel measurement along the buried plant route should be made. For an aerial plant on utility poles, a pole attachment agreement with the pole owners should be initiated and in the works. Once strand mapping is complete, make-ready work can commence. Since the measuring wheel is a low cost and a simple means of establishing the cable system length, cable operators should keep several handy for measuring added plants as well as subscriber drop lengths. Such a wheel is shown in Figure 2-27.

When the measurements are completed and the distances are entered on the map, then the poles and the route of the cable plant are known. At this

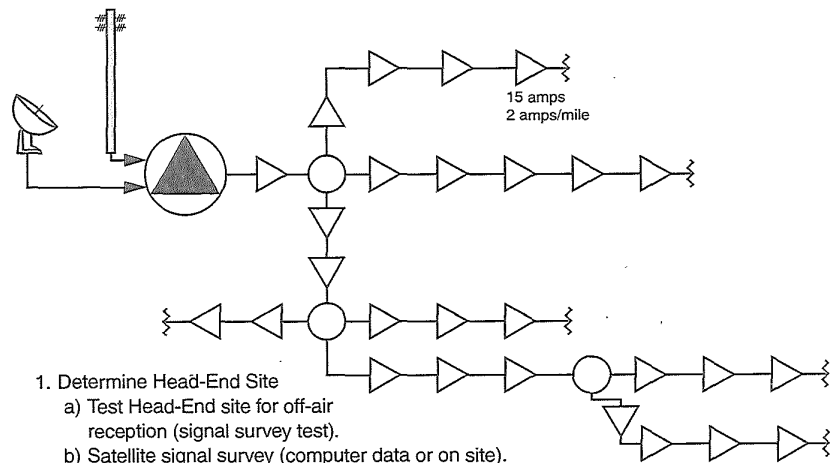
Figure 2-27
Measuring wheel



time, two projects can be completed at the same time. The first is the make-ready survey with the pole owners and is often a three-party survey between the cable operator representative and representatives of the telephone and electric companies. Each pole that is to be used for the cable system is examined to determine if there is proper space for the cable system. If any of the telephone or electric wires have to be moved to make room for the cable system, the cost is charged to the cable system. Most cable systems are well aware and are experienced in the use of leased space on the local utility poles. For underground or buried cable plants, only permission from the municipality is needed to perform the work. Responsibility for any damage to an existing buried plant such as telephone, power, water, sewage, and gas falls on the cable operator. It is usually the responsibility of each plant owner to mark-out their respective plant on the request of any of the other companies.

The Trunk System Once the system routing has been established, the trunk layout can be designed. This can be projected by the engineering department based on known areas of system expansion. An example of a trunk layout is shown in Figure 2-28. From this point, a system design can

Figure 2-28
Trunk amplifier
routing needed to
cover the service area



2. Define service area - miles/roads.
3. Draw skeletal trunk route, determine miles.
4. Calculate amplifiers/mile of selected trunk cable.
5. Go back and make any changes in routing, cable size to cover plant layout.
6. Now cost factors can be considered.

either be done manually using a pocket calculator or a more sophisticated computer. Several versions of software are available for personal computers and some are more involved and complicated than others. Computer-aided design and drafting programs have been around for some time. Most current ones can produce simultaneous trunk/feeder designs complete with tap values, port signal levels, amplifier input/output levels, and noise and distortion values, as well as a complete bill of materials. Since such software, computer, and plotting equipment is expensive, it is more cost-effective to have such work contracted out. Currently, several such design contractors exist throughout the country and most provide cost-effective designs in a timely manner.

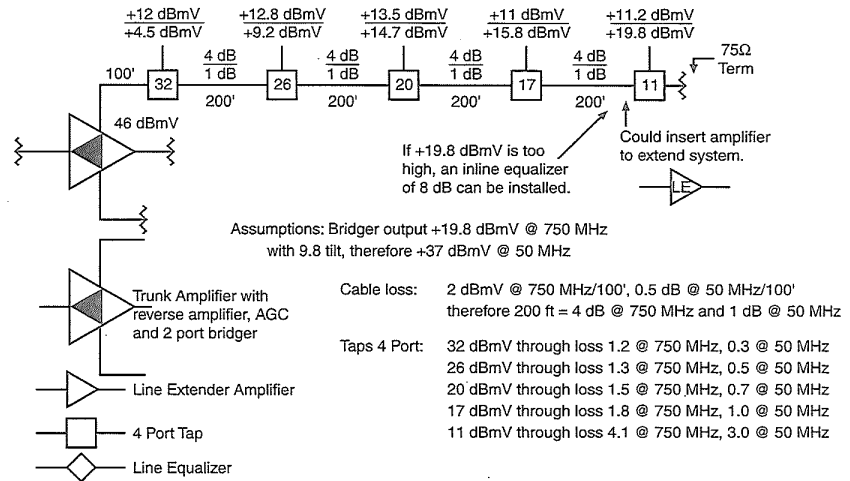
The Bridging to Feeder System The feeder or distribution system contains the subscriber taps, which are the part of the system that produces revenue. Thus, it is extremely important that it is also properly designed and constructed. Essentially, the feeder system is bridged off the trunk system through a bridging amplifier module installed in a trunk amplifier housing. From this bridging amplifier, the distribution cable delivers a signal to a series of subscriber taps. When this signal level decreases sufficiently, a line extender or distribution amplifier is required to increase the signal level for another series of taps. Most wide-band 750-MHz systems limit the number of distribution amplifier cascades to two amplifiers. Figure 2-29 shows a section of a distribution system, displaying what happens to signal levels along the distribution cable plant.

Notice that at the bridger output the signal has a 9-dB slope and, due to taps through loss and normal cable loss, the signal level at the last tap port nearly has a 9-dB tilt (reverse of slope). The higher the upper frequency limit becomes, the more severe the tilt becomes. Thus, the insertion of an inline equalizer before the last tap will provide signal correction. If the system is to be extended beyond the last tap, however, a line extender amplifier with a proper equalizer will be required. Normally, most systems limit the number of line extender amplifiers to two in a cascade. This results in three cable sections of five or six four-port taps, servicing 65 or 70 homes.

As the upper-band limit is expanded from 750 MHz on up to 1 GHz, the spacing between amplifiers for both the trunk and feeder systems shrinks. Now more amplifiers per mile are required as well as more power supplies to feed them. The constant fear is that the build-up of noise and amplifier distortion products would limit the system length or reach. In some instances, it becomes possible to change system routing to control noise and distortion problems, but nothing can be done about the high power consumption of a wide-band coaxial cable system plant.

Figure 2-29

Example of a
distribution section
of a cable plant



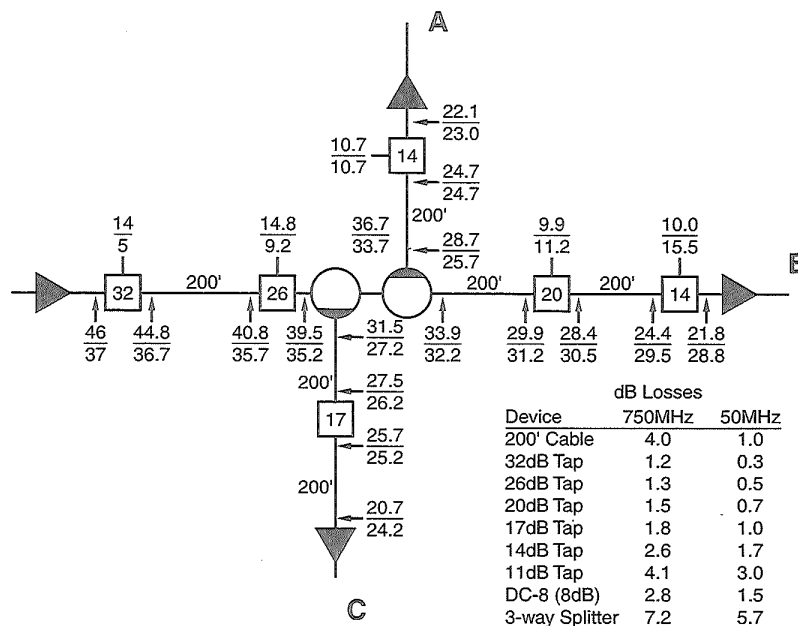
Cable System Splitting and Coupling Cost- and signal-effective branching of a cable television distribution system is very important. Maintaining proper signal level at the tap output port is of utmost importance to subscriber service quality for 750 MHz and higher systems. The approximate loss of RG-6 90 percent braid cable is 5.5 to 6 dB/100 feet. Therefore, a system should have a tap port level of at least +10 dBmV at the 750 MHz frequency. Proper drop cable shielding effectiveness is also necessary to control signal leakage and ingress.

You will often have several choices for branching within a service area design. If a manual design method is being used, the designer can ponder the various choices, taking signal level and cost factors into consideration. Signal splitters and directional couplers are the passive devices used for system street branching. Figure 2-30 and 2-31 illustrate two methods serving the same residential street layout. One method employs a balanced output splitter and the other one uses directional couplers. Figure 2-30, using two direction couplers, has two short branches with one four-port tap each and one long branch with two taps before a line extender is required. Figure 2-31 on the other hand could use two taps in three directions with the last tap a terminating tap before a line extender amplifier is required to extend the system.

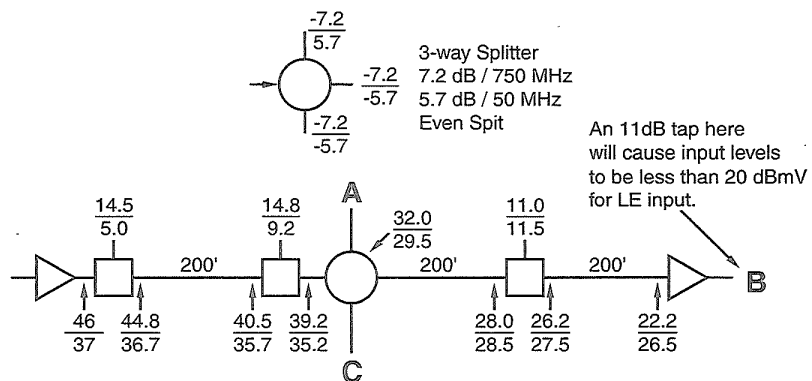
Computer-aided design and drafting programs keep a running tabulation of signal levels. When this level approaches a predetermined level, then an amplifier is needed at that point to continue the cable run. Where

Figure 2-30

Directional couplers
used to branch to A,
B, and C


Figure 2-31

Balanced 3-way
splitter for branches
A, B, and C



Note: All signal levels are +dBmV
Top figure is @ 750 MHz
Bottom figure is @ 50 MHz
Legs A, B, and C are identical

branching is required, the designer operating the CAD system can make the branching choices. When an amplifier is inserted, the program then annotates the system map with such parameters as input-output level, pad value, equalizer value, and carrier-to-noise and carrier-to-distortion calculations. These parameters can be very useful when compared to actual system measurements at initial proof of performance time. Trunk system splitting and coupling is equally important in determining the system network topology. A system designer should have a good general idea where any areas of future expansion might be proposed. Designing in some additional trunking during an initial build can often pay off down the road when a new area is developed. This information can only be known by the people responsible for the system service area determination.

Cable System Electronics

Cable system electronics have come a long way from where it started, from vacuum tubes to transistors and now to *integrated circuits* (ICs). Today's cable amplifiers have more gain, higher output operating levels, improved noise and distortion figures, and less power consumption. Equally important is the high construction quality that gives the industry a superior, more reliable device.

The industry has also become more knowledgeable about the metallurgy involved in cable systems, resulting in corrosion-resistant and weather-tight amplifier housings. Modular construction of the amplifier sections has increased the flexibility and serviceability of the present-day cable amplifiers. Most cable amplifiers can be operated at more than one power supply voltage. Most systems operate at 60 volts a.c. and more progressive systems operate at 90 volts a.c. Jumpers in the power supply section can be set to select the proper system voltage. Also the stability of the amplifiers has been improved.

With proper thermal compensation circuits along with automatic gain and slope systems, present-day amplifiers can provide many years of service. In many cases, a properly designed and constructed cable system will cause so few problems, service and technical personnel do not get enough service experience. When things do break down, a lot of head scratching results trying to remember where to start and what to do.

Cascaded Amplifier Theory The theory of cascaded amplifiers has been well known for many years. Radio communications people worked

with short cascades to solve antenna pre-amplifier and strip amplifier signal distribution problems. Receiver designers used the theory to design multistage IF amplifiers. Telephone company engineers used cascaded repeater amplifiers in long-haul or long trunk lines where telephone voice channels were multiplexed on a coaxial cable. Double side-band AM techniques were used where one voice channel occupied the upper side-band and another voice channel occupied the lower side-band of a carrier. The carriers were in the 10 to 100 KHz range and groups of channels were formed according to CCITT international specifications. Telephone traffic was routed through coaxial cable-cascaded amplifier systems for much of the transcontinental runs. This technique was also used in microwave radio relay systems where the channel groups operating in the KHz bands were frequently converted to microwave carriers and were relayed by microwave hops. The microwave carriers could be converted to the lower frequency ranges used on the coaxial cable system. Many of the early cable television engineers and technicians found a lot of information about cascaded amplifier techniques in the technical papers published by the telephone companies.

Cascaded amplifier fundamentals appear in Appendix A. Most people familiar with the theory use the mathematical formulas shown in Figure 2-32 and often work with them, designing system additions and extensions using a scientific pocket calculator.

As the upper frequency limit of cable systems increased, and performance specifications as well, the number of amplifiers in cascades increased. This should be easily understood since the cable loss increased as the service bandwidth increased, so more amplifiers were needed per mile. Also, as better carrier-to-noise ratios and carrier-to-distortion figures were needed, the number of amplifiers allowed in a cascade decreased. Such problems

Figure 2-32
Noise and distortion
formulas for a
cascade of "n"
amplifiers

Noise: $(C/N)_n = (C/N)_{n=1} - 10 \log n$

Composite second
order distortion (CSOD): $(C/CSOD)_n = (C/CSOD)_{n=1} - 10 \log n$

Composite
triple beat (CTB): $(C/CTB)_n = (C/CTB)_{n=1} - 20 \log n$

Cross modulation
distortion (XMOD): $(C/XMOD)_n = (C/XMOD)_{n=1} - 20 \log n$

n = number of amplifiers in a cascade

required many older cable systems to limit their bandwidth and the number of service channels. This problem is made clear by Example 2-4 where the upper frequency is 750 MHz with 110 channel loading. The sample calculations indicate that the amplifier cascade has to be limited to about five amplifiers if the specifications for distortion are to be adhered to. Clearly long cascades are prohibited for wide-band high-quality cable systems. Essentially replacing the coaxial cable trunk cascades with fiber optical systems enables cable operators to provide 110 channels at 750 to 1,000 MHz.

Trunk Amplifiers ASC/AGC Trunk amplifiers then became available with a variety of characteristics such as push-pull, power-doubling, and feed-forward. Push-pull amplifiers provided the cable operators with an amplifier that had good second order distortion characteristics. Adding *automatic gain* (AGC) and *automatic slope control* (ASC) provided cable operators with the workhorse of the industry. Several manufacturers offered such push-pull AGC/ASC amplifiers. Power-doubling techniques, as shown in Figure 2-33, gave the industry higher output levels needed to extend system reach.

As bandwidth requirements increased and system length as well, the feed-forward amplifier was developed. This technique is shown in Figure 2-34 and it does for third-order distortion what push-pull did for second order distortion. Some cable operators extended cable cascades to nearly 45 amplifiers in a cascade for a 450-MHz 60-channel cable plant. Such systems operated at either an IRC or an HRC that allowed the third-order distortion levels to be relaxed by approximately six to nine dB.

Essentially, any distortion products were moved to the edge of the television screens, which was less objectionable. Cable system head-ends had to be phase-locked to a reference comb generator, causing the cable operator a lot of expense. Each modulator and signal processor had to have phase-lock circuitry added so they could be phase-locked to the reference generator. Often phase-locking at the head-end, as well as the use of feed-forward amplifiers, was necessary for cable operators to increase bandwidth and system reach.

Bridging and Distribution Amplifiers Bridging and distribution amplifiers operate the feeder cable system containing the subscriber taps. It is imperative that the proper signal level at the tap output ports be maintained. Systems operating at 750 MHz with 110 channel loading will have difficulty feeding long subscriber drop lengths with adequate signal levels.

Example 2-4750 MHz, 110
channel loading

For a single amplifier with a noise figure of 10 dB and an input signal level of +15dBmV, can be found using the following formula:

$$(C/N)_{n=1} = 59 \text{ dBv} + \text{signal input (dBmV)} - \text{noise figure} \\ = 59 + 15 - 10 = 64 \text{ dB}$$

To find 'n' for an end of cascade C/N of 49 dB.

$$(C/N)_n = (C/N)_{n=1} - 10 \log n$$

$$49 = 64 - 10 \log n$$

$$-15 = -10 \log n \quad \log n = 1.5$$

$$n = 32 \text{ amplifiers}$$

For a carrier to second order distortion specification of 50 dB, the cascade number can be calculated by:

$$(C/SOD)_n = (C/SOD)_{n=1} - 10 \log n$$

For a single amplifier C/SOD = 63 dB

$$50 \text{ dB} = 63 \text{ dB} - 10 \log n$$

$$-10 \log n = -13$$

$$\log n = 1.3$$

$$n = \log^{-1} 1.3$$

$$n = 20$$

For a C/CTB and C/XMOD of 50 dB.

$$(C/CTB)_n = (C/CTB)_{n=1} - 20 \log n$$

For $(C/CTB)_{n=1} = 64 \text{ dB}$

$$50 \text{ dB} = 64 \text{ dB} - 20 \log n$$

$$-14 = -20 \log n$$

$$\log n = 0.7$$

$$n = 5$$

For $(C/XMOD)_{n=1} = 65 \text{ dB}$

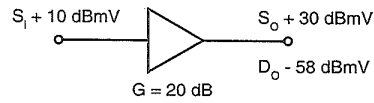
$$50 \text{ dB} = 65 \text{ dB} - 20 \log n$$

$$-15 = -20 \log n$$

$$\log n = 0.25$$

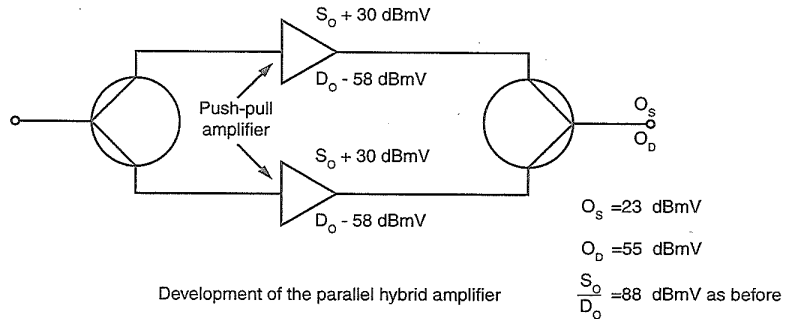
$$n = 5$$

Figure 2-33
Power doubling
amplifier



$$\frac{S_o}{D_o} = +30 - (-58) = 88 \text{ dB} \quad \frac{S_o}{D_o} = 88 \text{ dB}$$

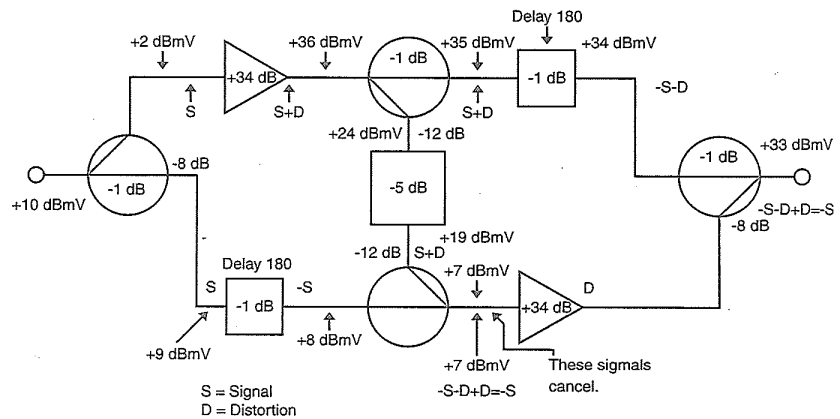
Single Push-Pull-Type amplifier



Development of the parallel hybrid amplifier

S_o of parallel hybrid amplifier is 3 dB higher
with same $\frac{S_o}{D_o}$ ratio as a single amplifier.
A 3 dB improvement is equivalent to doubling
the power.

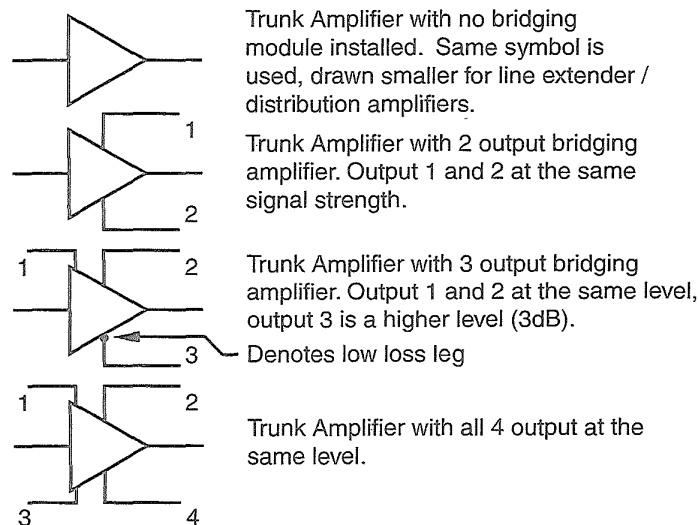
Figure 2-34
Feed forward
amplifier operational
example



Since the trunk amplifier's purpose is signal transportation, it is the job of bridging and distribution amplifiers to distribute the signal. The bridging amplifier module is installed in a trunk station housing and has the map symbol configuration, as shown in Figure 2-35.

The distribution cable system consisting of subscriber taps, signal splitters, directional couplers, and line extender amplifiers connects to the bridging ports. A cascade of subscriber tap values in a descending order usually connects to a bridging port. When a signal split is needed, an amplifier may also be required to compensate for the tap through loss and or splitter or directional coupler loss. System design computer programs keep track of the signal level values and indicate when an amplifier is required. Often, the exact placement is made by the program operator. The amplifier location can then be placed on a more convenient pole or pedestal, making maintenance and repair work easier and less hazardous. It is the distribution plant that often provides the greatest number of design choices available. In general, bridging and line extender amplifiers operate at high gain and output levels; consequently, the feeder cascades are limited to two amplifiers.

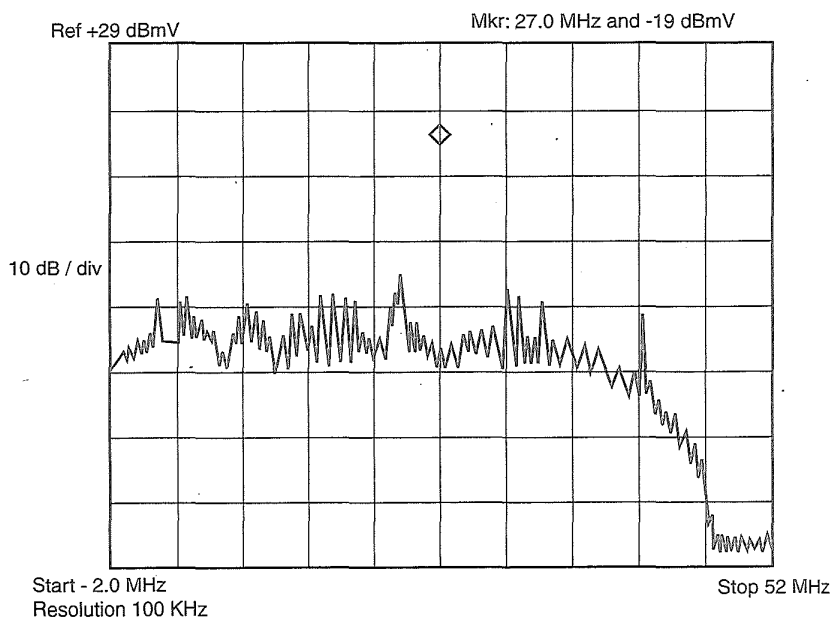
Figure 2-35
Map symbols for
trunk bridging



Reverse Amplifier Considerations—Two-way Services Systems using two-way services have reverse-amplifier and duplex filters installed in the amplifier housings. These amplifiers operate in a reverse direction to the main downstream cable system. A band of frequencies is allocated for the reverse system and duplex filters are used to separate the downstream and upstream frequency bands. The 5- to 40-MHz upstream band is below the 55- to 750-MHz downstream band and is referred to as the sub-split reverse system. When the reverse band is placed in the middle of the downstream or forward band, it is known as a mid-split system. Placing the reverse band at the upper band edge results in what is termed a high-split system. The most common of the reverse bands is the sub-split system. This narrow band can be used for approximately seven television channels, but the tightness of the system determines how and where the noise build-up occurs in the reverse band and the placement of the reverse carriers within the band.

The noise level in the active reverse band can be measured using a spectrum analyzer. A typical spectrum analyzer display is shown in Figure 2-36. Before using the reverse system, the amplifiers and filters have to be installed. Since the cable loss is much less in the sub-band, it determines whether an amplifier is needed at every station.

Figure 2-36
Noise spectrum of a
typical sub-split
reverse



Essentially, the design and projected performance calculations for each path in the reverse direction should be done. Again, many *computer aided design* (CAD) programs contain sections on reverse system design. The reverse system should be activated on a leg-by-leg basis. When activating a reverse cable section, it will most likely be necessary to tighten or repair any leaky connectors, correct drop problems, and install reverse band stop filters in drops to reduce noise and signal ingress in the reverse band. In short, the system has to be reworked on a section-by-section basis. Now signals can be placed and balanced on the reverse system.

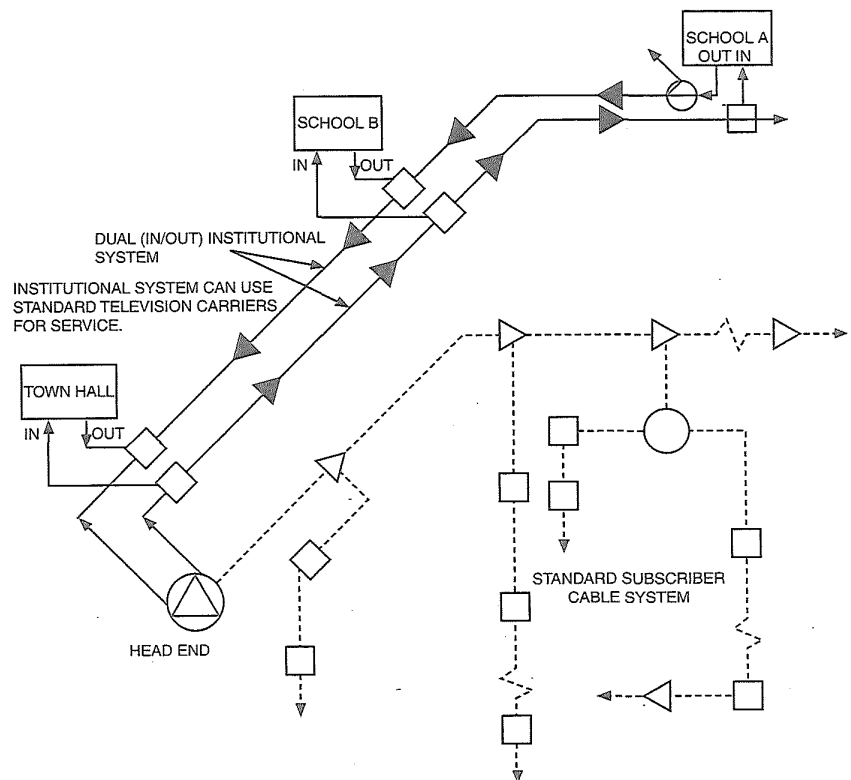
A spectrum analyzer measurement of the return signal can be measured at the head-end. Several manufacturers provide instruments that are especially useful in balancing and monitoring the return signals. It is a constant maintenance problem to keep both the forward system from leaking signals and the return system from signal and noise ingress. Essentially, this means that all connector cables and device housings have to be tight and corrosion-free. Reverse system testing and maintenance topics will be studied in detail in Chapter 6, "Cable Plant Testing and Maintenance."

Reverse or return systems have several areas of application in the cable television industry. One earlier application was to obtain programming from local schools, municipal meetings, and so on, which was done live and sent back to the hub/head-end for downstream broadcasts to the subscribers. After local groups found how much work was involved in producing an hour's programming, interest decreased dramatically. Most subsplit return systems with two to four television channels available are found to be adequate for most community requirements.

Some of the more urban communities required a municipal institutional cable system called an "I" loop. Such systems could be simply a few sections of cable plant operating in both directions connecting several municipal locations together. One usual connecting point was the local cable operator's hub/head-end. An example of such an institutional loop is shown in Figure 2-37. Such a system can be used to carry a full spectrum of signals in each direction carrying video (TV), voice, and/or data on modulated RF carriers. Switching functions at the hub/head-end could broadcast any selected channel(s) over the forward system for subscriber viewing. This type of system was definitely a significant financial burden for the cable operator and, fortunately for most, few such systems were built.

Maintenance of such systems is essentially the same as for the forward system. For wide-band forward and return systems, both a high- and low-pilot carrier are required at the sending ends. These carriers could be modulated with television signals and used as an ordinary channel, but they

Figure 2-37
Institutional cable
system overlayed on
subscriber cable
system



have to remain on the system used or unused as the pilot carrier reference needed to maintain proper system gain and slope.

Construction Practices

Construction practices and construction equipment have definitely improved since the early days of cable television systems. The method for servicing an aerial plant used to be climbing the poles with a set of hooks and a belt. Most people learned to climb poles from earlier experiences working for either the telephone or electric company. Some learned to climb from a tour in the service, usually the U.S. Army Signal Corps. Essentially, the Signal Corps adopted telephone company methods and specifications. Therefore, former Signal Corps veterans often became employed by the cable television industry companies and learned the technical side during

the early start-up years. Those that did not climb often used extension ladders against the poles.

Some innovative cable system technicians experimented with vehicle-mounted ladders. In a short time, the hydraulic lift truck became available and soon became affordable and practical for cable television system use. As suburban areas grew and became more populated, underground utilities including cable television systems became more attractive. Many system operators felt their plant was safely underground and at ground level for easy maintenance. Smaller and more affordable trenching machines made such installation financially viable.

Aerial Construction Methods Aerial construction methods have definitely undergone evolutionary changes. From a labor-intensive manual operation to modern hydraulically operated lift trucks with hydraulically operated drills, saws, and hoists, present-day construction practices have drastically improved. Some old-timers remember climbing the poles and boring through a pole with a bit brace and ship's auger. Nowadays a person is lifted up the pole in an aerial basket where the pole is drilled in about a minute and the through-bolt washers and nut are installed in another minute, enabling many more poles to be framed in a day. Such efficiency did not result in many cost reductions since the equipment costs had to be repaid and the operators paid more for being more experienced, but a lot more plants could be built in a shorter time frame.

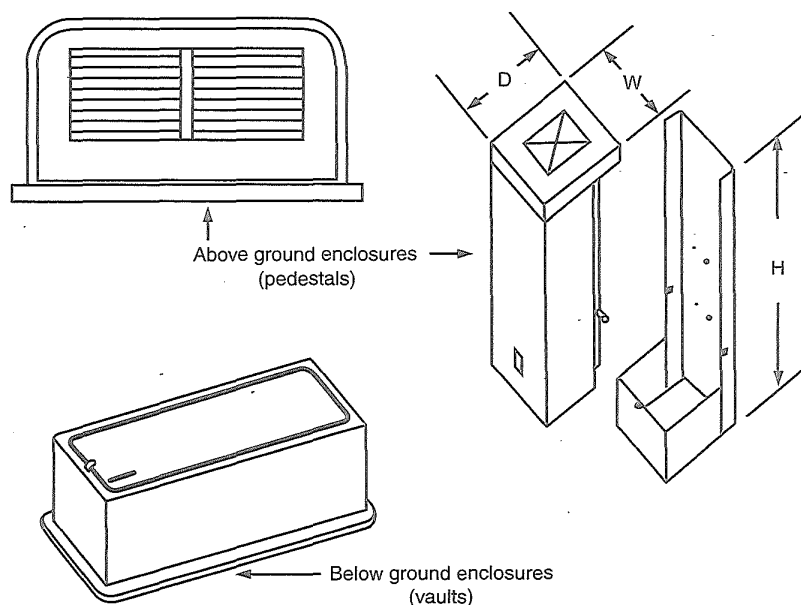
Pole line hardware also improved over the years and more attention was paid to the effects of dissimilar metals on corrosion. Therefore, better materials were introduced. Usage of corrosion-resistant materials such as a Monel metal, stainless steel, and a variety of plastics produced a more reliable cable plant.

Underground Construction Methods Underground cable plant construction in both methods and materials has changed more than aerial plant. First, the method of placing the plant underground has certainly progressed from "pick and shovel" methodology. Opening a trench has changed from a back-hoe machine to a chain-type trencher that opens a narrow trench, spilling the removed earth into a neat row along one side of the trench. Usually stones are manually removed and often a layer of gravel is placed in the bottom of the trench. A trench of this variety can be used with direct burial cable. Often PVC-rigid conduit is placed in the trench with an installed pull-rope to facilitate pulling the communication cable through at some later time. Semi-flexible conduit is placed in the trench and some manufacturers provide the conduit with the cable already installed. Several

conduits can often be placed in the same trench. Many trenchers also have an optional back-fill blade that can plow the spill back into the trench. Trenching machines can provide trenches from very shallow to several feet deep. For most communication purposes, a depth of 24 to 30 inches is appropriate. A favorite method of placing cable underground is using a cable plow. As mentioned in Chapter 1, "Introduction," the two types of cable plows are the vibratory plow and the stationary plow.

Since an underground plant requires access to the active and passive devices, a variety of equipment enclosures are designed for underground plant servicing. These enclosures fall into two categories: aboveground and underground. The aboveground enclosures are either metal or plastic pedestals, and the underground enclosures are either plastic or concrete vaults. The vaults are usually fitted with an appropriate cover that either has to be pried open with a special tool or unbolted with a special wrench. The aboveground pedestals have either a locking device or special tool. These measures prevent unauthorized tampering with the equipment. More progressive cable operators that have electronic monitoring capabilities, called status monitoring, can integrate an alarm system for vault or pedestal protection. Some of these pedestals and vaults are shown in Figure 2-38.

Figure 2-38
Types of pedestals
and vaults.

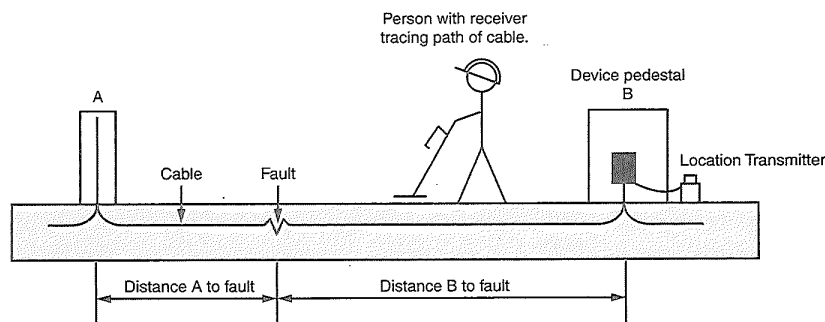


Underground cable plants have to be mapped and properly marked so that service and maintenance can be done at a later time. Unlike an aerial plant, an underground or buried plant, as it is often called, cannot be seen. Therefore, the exact location of cables has to be known and appropriately mapped. Most of the problems with a buried plant result from the careless cutting and digging by other underground utilities. The installation of traffic signs often causes service interruptions for the cable, power, and telephone operators. Thus, various measures are employed to prevent damage to an underground cable plant. The installation of a yellow or orange plastic warning tape placed over the cable a few inches below the ground's surface offers some protection against digging up the cable. Warning decals placed on the pedestals can also alert others that facilities are buried nearby.

Cable operators with an underground cable plant should have some type of cable *Time Domain Reflectometer* (TDR) available to find the distance from one point to the fault. Making a measurement from each end of a cable with a fault (a cut or a crush) will give a close location of the fault. Also, cable operators need some type of cable location instrument, of which several types are commercially available. Essentially, they place an electrical signal on the cable that is detected aboveground by a receiver. In most cases, the transmitted signal is placed on the cable's metal outer sheath at one end of the cable run and a person with the receiver walks along the cable run with the receiver, detecting the path of the cable by marking it with either spray paint or garden lime.

Once the distance to the fault has been determined and the path of the cable is found, the close location of the fault is identified. Following this procedure minimizes excessive digging and makes repair of the problem much faster. This method is illustrated in Figure 2-39. Underground plants are becoming more and more attractive to cable operators simply for the reasons of maintenance and safety from vehicle accidents.

Figure 2-39
Location of buried
cable path



Splicing and Connectorizing Cable connectors have also certainly improved over the years. One problem with connectors is what is known as a pull-out, in which the cable is simply pulled out of the connector, causing a loss of signal and cable power. This is the most catastrophic problem with a connector.

Another problem is corrosion and connector deterioration over time. Systems with such problems will be faced with accompanying outages and subscriber complaints. Since we live in the time of corporate mergers, several connector companies have been bought out and or consolidated. More attention is consequently being paid to the metallurgy involved with cable plants and the problems of mixing various metals. Certain metals when in contact with one another in a moist and corrosive climate (such as air pollution or acid rain) can cause rapid deterioration of the plant. Also certain metals used together in housing and fastenings can cause threads to seize. Different metals have different thermal characteristics that can cause expansion and contraction problems over seasonal temperature variations. Fortunately, several excellent companies still provide high-quality connectors to the cable television industry.

Another consideration cable operators have to make is the ease of connectorizing the system, which means the ease of preparing the cable and installing the connectors. Proper tooling is a necessary requirement. Present-day connectors require that some of the dielectric has to be removed so the internal R.F.I. sleeve can fit under the aluminum sheath. This operation is known as coring and can be done with a manual corer or one fitted on an electric drill. The drills used by cable splicers when connectorizing a plant can be powered by electricity (portable), compressed air, or by hydraulic means. Use of powered coring methods speeds up the connectorizing process. Once a connector manufacturer is chosen, the application's engineering department and/or customer service department will usually be most helpful to the cable operator, providing installation and tooling information. Most splicing contractors are familiar with all the available connectors and the installation methods required. Proper installation is most important in keeping the power flowing and the signal inside the cable.

Coaxial cable systems have to conform to the FCC's required signal leakage specifications, testing the plant several times a year for signal leakage. Connectors that prevent signal leakage also shield the plant against extraneous signal ingress and noise ingress. Improper connectors do not give a good impedance match, which can result in standing waves and signal echoes, which result in ghosting of the TV picture. By now, it should be evident that good connectors properly installed will provide good cable plant

operation over the years. Some of the cable preparation tools appeared in Figure 1-6 in Chapter 1.

Grounding and Bonding Requirements Proper system grounding and bonding is extremely important to protect cable systems from the effects of lightning and power system surges. For aerial plants, the practice is to bond at the first and every 10th pole, as well as the last pole in a cable run. Some pole attachment agreements call for different grounding and bonding practices that must be followed. In most cases, all power supply locations for either aerial or underground plants must have a separate ground rod. Ground wires on utility poles often require the installation of protective pole molding to protect the ground connections. Special bonding clamps are used to bond copper wire, usually number 6 (AWG) soft-drawn copper wire, to the galvanized steel messenger strand supporting the aerial cable system. These clamps are usually plated brass. Some aerial bonding methods are shown in Figure 2-40.

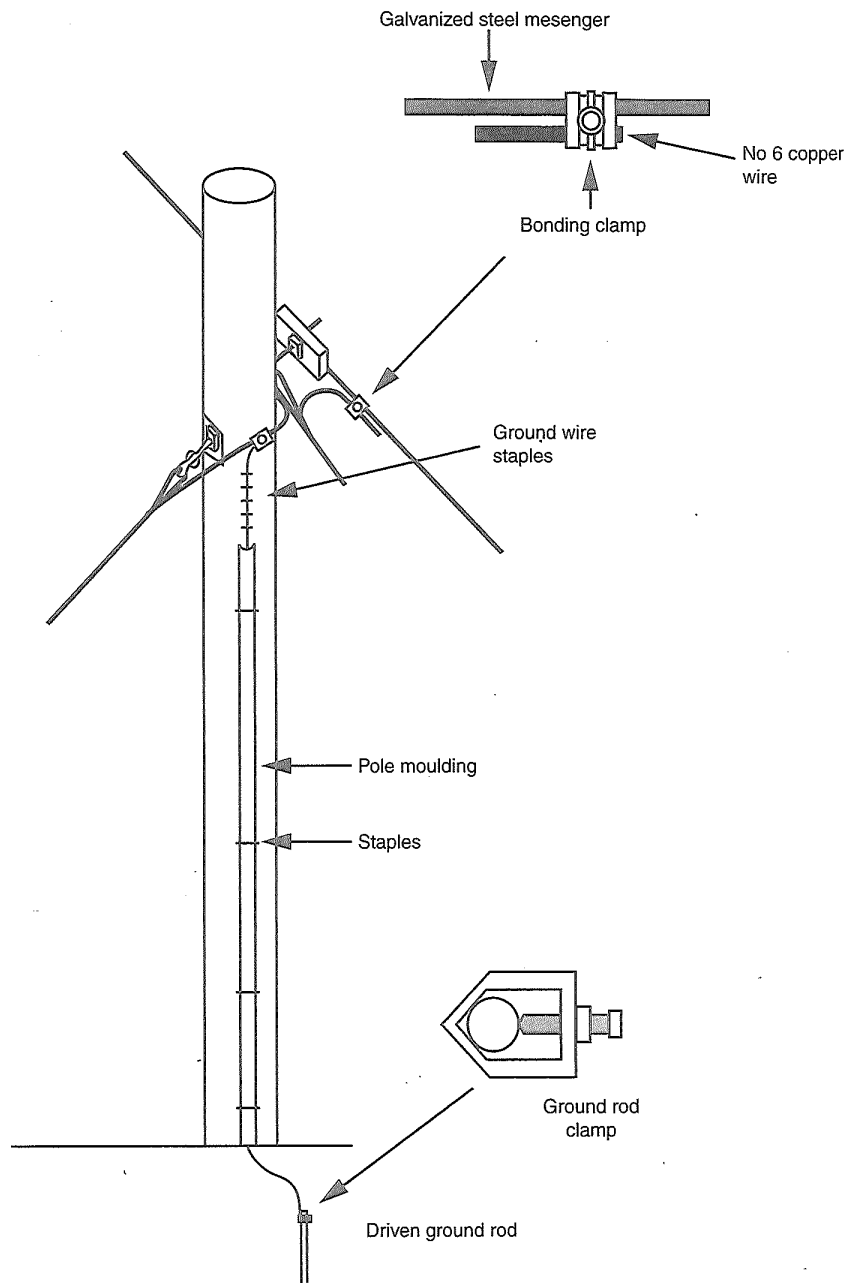
Grounding and bonding at the head-end and/or hub distribution points is crucial for protecting sensitive electronic equipment from lightning and power surges. Presently available are surge protectors that can be wired into the power entrance panels of hub/head-end facilities. Such devices can protect all the equipment inside the building that is connected to the inside power distribution system. Emergency stand-by power systems of the external engine-powered variety also have to be properly grounded and bonded to the central grounded electrode. Essentially, the main ground electrode is connected to a system of driven ground rods and the power entrance ground. A hub/head-end ground and bonding plan is shown in Figure 2-41.

Subscriber Equipment and Signal Security

Subscriber- or customer-used equipment provided by the cable operator is essential to the delivery of a high-quality product. This equipment should be user-friendly and attractive in the television viewing system since it appears near or on top of the subscriber's TV set. Unfortunately, the use of a set-top cable television converter makes the subscriber's TV set remote control quite useless since channel selection is done by the set-top cable converter, as discussed earlier. This also makes VCR recording for the subscriber quite difficult and compounds the problem of the VCR remote control. Signal security in most cable systems is performed within the cable converter where the premium channels are decoded or descrambled.

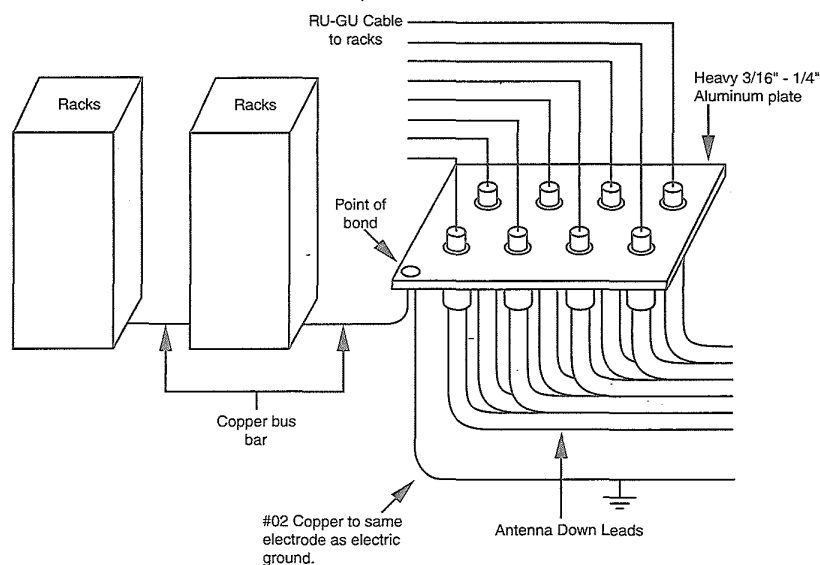
Figure 2-40

Example of an aerial
plant grounding and
bonding



**Figure 2-41**

Example of a head end ground/bond system



The Set-top Converter The set-top converter has evolved over the years from the simple mid-band to the super-band channel selector. Today most cable converters still perform channel selection and operate with their own remote control. Decoding and descrambling takes place within the converter for the premium pay channels.

Ordering premium channel programming is still mostly done by a phone call to the cable operator's subscriber office. In many instances, cable operators use what is known as addressable converters, and when a subscriber calls the cable office and orders a premium channel or a pay-per-view program, the converter is authorized by a downstream data channel. This authorization activates the converter to decode the premium programming ordered. Cable systems with active reverse systems can place the ordering requests through the bidirectional set-top converter to the hub point. The subscriber can now order a particular pay-per-view program by using the set-top remote control to place the order. This type of television service is enough to make us all couch potatoes.

Positive/Negative Signal Trapping Prior to such sophisticated converters, signal security was provided by what is known as signal trapping. The unsubscribed premium program channels were trapped out (prevented) of the subscriber's drop cable. This was done at the tap port feeding the subscriber's drop cable.

Trapping devices appear as one of two types. A device that prevents the premium signal from entering the subscriber's drop is essentially a narrow-band stop filter, known as a negative trap. The other trapping device is what is known as a positive trap. At the hub/head-end, an interfering signal is placed on the premium channel that renders the channel unwatchable. The positive trap removes the interfering signal from the premium channel, now rendering it watchable. All subscribers not wishing to have the premium channel will need a negative trap, while a subscriber wanting the premium channel will need a positive trap. Systems that have a negative trap scheme with few subscribers taking the premium service will need a lot of negative traps. For such systems, a positive trap scheme will be more cost-effective since the few premium program takers will need the interfering signal removal traps.

Since these traps appear at the tap port, a system accounting (audit) of subscribers taking or not taking the premium service can be made by a simple drive-by for observing the aerial traps. For underground systems where the taps are in pedestals, the pedestals should be locked to prevent tampering with the traps. Removing a negative trap allows the premium program to be seen. A positive trap of the proper type is needed to remove the interfering signal for the premium channel to be seen. Therefore, signal security is better using the positive trap method since an appropriate device in the drop has to be in place in order to receive the premium signal. Unfortunately, unscrupulous people sell such devices to those people who wish to steal the service that are usually inserted within the TV set where it is unseen. Some people use dummy negative trapping filters at the tap port that look like a trap but just pass the signal through.

Scrambling/Descrambling Scrambling or encrypting a television signal, rendering it unwatchable, is indeed a better and more secure method to prevent stealing or unauthorized signal use. This is a more elaborate and expensive method, but many cable operators feel it is worth the expense.

Several methods are used to scramble or encode the premium channels. One method is to remove the horizontal synchronizing signal, commonly known as sync suppression. This type of scrambling is, of course, analog and works well with the standard NTSC video format. Inverting the horizontal synchronizing signal with some form of alternating pattern offers a higher level of scrambling. Such methods working in conjunction with subscriber terminal addressability are still being used by many cable operators. With the arrival of digital television, digital encryption techniques will certainly improve signal security to a very high level. This apparently is what the cable television industry has been waiting for.

Addressable Converters Addressable converters, or as they are known, addressable set tops, do two things for the cable operator. The most important consideration is that subscribers can order program services over the telephone and the cable operator can then download the authorization codes to the set-top converter. Thus, the converter is activated to automatically make the changes and descramble any of the selected premium services. Addressability enhances signal security since the set-top has its own address code where its location address is known. Now if this box is activated and stolen, and the service is not paid for, the box can be rendered inactive and hence useless.

Interactive Converters Interactive converters are those set-tops that can communicate directly with the hub/head-end. Such converters make pay-per-view channels quite easy to be seen by any of the subscribers and services can be ordered through the remote control directly. These converters can work the *video on demand* (VOD) systems some cable operators presently have in place. Converters operating in this manner must have a reverse path of communications back to the main signal distribution point. This reverse or return path usually operates in the sub-band (sub-split reverse) portion of the cable system. A relatively small number of cable systems have the return path in the mid-band or high-band that actually contains a wider return band, offering more equivalent upstream television channels. Interactive converters can be traced if stolen and detected in the wrong part of a cable system.

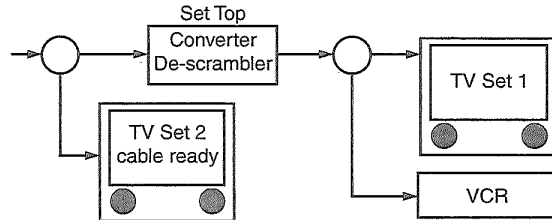
Connecting VCRs, TV Sets and Converters Connecting subscriber equipment to the cable system probably causes the most trouble for the subscriber. It is basically the set-top converter that causes the television set and VCR remote control to be ineffective in selecting television channels. This problem causes more complaints from subscribers with cable service. The use of switches to change or reconfigure the subscriber's TV-VCR hook-ups may help the situation. Also smart remotes (programmable remote controls) can be programmed to operate all of the subscriber devices.

This problem really resulted from the television manufacturer's inability to address the cable television industry's specifications. A possible solution would be for the TV set to operate at the intermediate frequency provided by the set-top box and the VCR. This subject has been under much discussion between cable operators and the consumer electronic manufacturers with the Cable Labs and the FCC advising at times. Several subscriber equipment connections are shown in Figure 2-42.

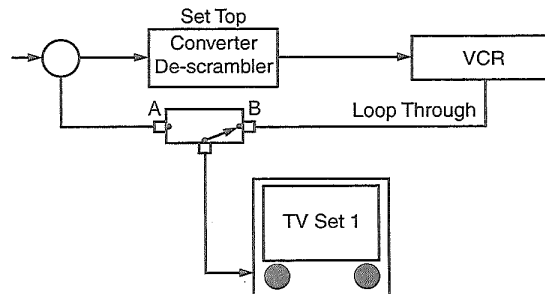
Figure 2-42

Adding another converter, T.V. set and VCR can make for a complicated home distribution system

ConfigurationA: TV Set 1 and VCR views the unscrambled channel tunned by the converter. TV Set 2 simply views any clear channel, if TV Set 2 is cable ready.



ConfigurationB: TV Set 1 can view any clear cable channel when A/B switch is in position A. VCR can be recording a pay TV channel selected by the converter. For the TV set to view the pay channel, switch to position B and tune the set to the converter output channel.



The *National Cable Television Association* (NCTA) released a publication addressing the interconnections between the cable converter, the TV, and the VCR. This publication covered a large variety of interconnections using A-B switches, splitters and couplers, multiple converters, VCRs, and TV sets. Many homes subscribing to a cable service that are supplemented by a *Direct Satellite Broadcast System* (DBS) as well as a VCR can have an elaborate switching distribution system.

A word of caution: when a subscriber has an off-air roof-top antenna connected to the switching coupling network, care should be taken to prevent the wide-band cable system from being connected to the antenna. This could cause some serious interference problems with many homes in the neighborhood as well as the cable operator. Remote as it may seem, it can

happen and it has happened before. Such signals can disrupt air traffic communications as well as some of the law enforcement and safety mobile radio services. Another word of caution is to make sure switching and coupling devices are the appropriate ones to use for cable television use. Some available devices are made for base-band video and are not appropriate for higher RF frequencies.

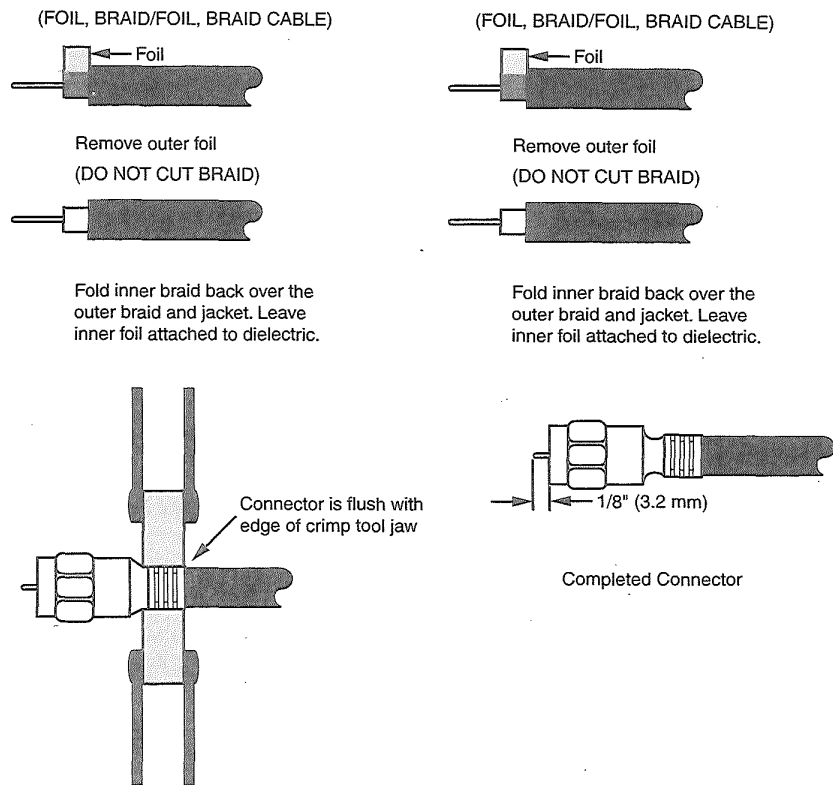
Probably one of the most important considerations with subscriber-connected equipment is the connectors themselves. Some of these connectors are used by the subscriber and are obtained at local electronic outlets, hardware stores, and homeowners' outlet stores. Unapproved tools and techniques are often used and hence the connectors are improperly installed. This is beyond the control of the cable operator who only learns about it through resulting service calls reporting poor signal problems by the subscriber.

The connector used to connect subscriber equipment is the "F"-type connector, which had its infancy in the MATV industry. This connector evolved from a rudimentary connector with a separate one-eighth-inch crimp ring to a single-piece weather-tight connector that requires proper stripping, tooling, and a more precise crimp tool. Several manufacturers supply versions of these superior type "F" connectors to the industry. Most cable operators use this type of connector and have instructed their installer personnel in the proper installation procedures. However, a lot of the old connectors are still out there in many cable systems.

Changing these connectors is an expensive and labor-intensive procedure and is usually done during a system upgrade. These poor, early "F" connectors cause signal leakage, ingress, and noise problems that interfere with the use of an active return signal plant. When a cable system is planning a system upgrade requiring an activated return path, changing all the subscriber "F" connectors on an area-by-area basis is necessary in order to control the noise and signal ingress in the return path. Often subscribers not using the return path will have a filter trap at the return band frequencies, which will prevent signals or noise entering the return path from this location.

In many instances, cable systems discover signal leakage from a subscriber address during the usual periodic leakage testing required under the FCC rules. The usual procedure is to disconnect the subscriber drop and check the signal leakage level. If it goes away, then the subscriber will have to be contacted so an appointment can be made to make the necessary corrections. Since all of these costs have to be born by the cable operator, many cable systems avoid return path activation. An example of a current "F"-type connector and the accompanying cable preparation is shown in Figure 2-43. It should be obvious that this is indeed an improved connector that can be used with single and multishielded drop cables.

Figure 2-43
Example of a
currently used "F"
connector stripping
and crimping



System Testing/Proof of Performance

Cable television systems have to be completely tested on an annual basis for proper system performance parameters as required by the FCC under Part 76 Title 47 of the Federal Commission Rules of 1990. The first test period should be when the system is first turned on after construction is completed. A system operator should insist that the new system pass all FCC tests satisfactorily before final acceptance and the contractors are paid. In short, it should be a part of the construction contract in the final check-out and acceptance.

For the first three years, annual proof of performance tests are conducted on an RF basis, after which tests are performed on base-band signals on a three-year cycle thereafter. RF tests take place twice yearly and base-band tests are every three years. Systems with fewer than 1,000 subscribers are still exempt from proof of performance testing. Such systems consist of

neighborhood systems similar to MATV systems and evidently seem trivial to the commission. Systems with 1,000 to 12,500 subscribers have to be tested at six widely separated test points where at least one-third must be set at the most distant point from the central signal source. For systems greater than 12,500 subs, another test point needs to be added for every additional 12,500 subscribers.

Each system has to have in its company technical records a copy of the FCC rules and Regulations Part 76 Title 47. Test records have to be kept on file for a five-year period and are subject to inspection at any time by a representative of the commission. The test results also must include the test procedures, calibration data and dates for the test instruments used, and the qualifications of the persons conducting the tests. The test points are specified at the subscriber terminal, which in most systems is the converter output terminal. Since most converters are pre-tested, tests can be made at the end of a 100-foot drop from the system tap and can be corrected by the converter performance specifications.

Initial Performance and Testing and Balancing Initial system test results are important in setting the system performance standards. In most instances, a newly tested system never performs better than at turn-on time since system component and cable aging causes a gradual system deterioration. A properly maintained and operated system periodically tests and services a plant to maintain proper signal quality. This, of course, is just good business, giving quality service to customers.

The turn-on sequence of events is important when performing initial tests. The procedure is to turn-on plant distribution power, correcting any open or short circuit problems. Next, the pilot signals are injected into the system, and amplifier modules and power modules are installed in the trunk housings. At this time, each amplifier is roughly balanced on both the high and low pilots. Following this operation, a leakage test of the trunk runs is made so any further balancing will not compensate for a poorly impedance-matched plant. At the initial leakage test phase, the whole system can be swept using a sweep generator receiver instrument. This can be done on a system segment or a main trunk branch at a time. Lastly, the whole signal spectrum can be turned on and the system can undergo the final balance and leakage test. The results should be kept in the system file for future reference if any troubles should occur.

Often the costs of final testing are the responsibility of the prime contractor when the results prove to the system operators that the system is complete and operational according to the construction contract. Lending institutions holding the loan on the system may require either a consulting

engineer as an observer of the final testing program or an independent testing company to perform the test to the satisfaction of all concerned parties.

Signal End Level Testing The next most important test program is the periodic signal-level measurements of end points in the system. Unfortunately, many systems rely on the sporadic signal-level measurements made by drop installers or maintenance technicians making trouble calls. The measurement of system end levels on all cable channels can give a lot of information about how the system is operating. Seasonal variations of a signal level can indicate how well the thermal compensation and AGC/ASC systems are working. An analysis of this data either by a manual method or a computer program can indicate areas of the plant that need some maintenance long before the phones start ringing with trouble calls. Inexpensive graphics software can be used to present spectrum plots at the end points of the system.

For an aerial plant, a drop can be made at a tap fed from the last line extender and stapled down the pole. On the end of the cable, a connector installed with an F-81 barrel can provide a convenient point for a technician to connect a signal-level meter lead. The whole drop test point can be hidden behind pole molding. At the end of the test, the technician can remove the instrument lead and install a 75-ohm terminator to the test drop. Many instruments can provide the whole spectrum on an LCD display and many can store data in a solid-state memory. End-level tests can be made either on a monthly or bimonthly basis, or at least on a quarterly plan, so data can be accumulated over a significant temperature range.

Leakage & Ingress Testing CLI Another routine test that cable systems must perform is the signal leakage test required by the FCC. This test has to be done on a quarterly basis and the results must be kept in the company technical files. The *Cumulative Leakage Index* (CLI) parameter will be computed for a system at the completion of the testing period. Any problems with signal leakage should be expeditiously repaired with documentation on the cause, the fix, the date, and the personnel. The methods and technical specifications will be discussed later in Chapter 6.

Two basic test procedures can be used to obtain the data for the CLI. One is the fly-over method, requiring the use of an airplane flying over the system at a fixed altitude. Monitoring equipment onboard the aircraft will record the signals leaking from the cable plant. Once the signal levels and the location are known, the problem areas can be easily identified. The use of the satellite-based *Global Positioning System* (GPS) can also be a big

help in plotting the location of leaking plant. The second method employs vehicle-mounted antennas used to locate problem areas. Once these areas are found, technicians using probe antennas can pinpoint the faulty connectors and loose amplifier housing. Many cable systems use this method. Technicians doing installation and maintenance tasks can monitor the plant at the same time. Keeping a plant free of leakage will also keep it free of signal noise and ingress.

Summary of Testing This chapter essentially addressed coaxial-based cable television systems. Information in this chapter supported the more elementary nature of the first book, *Cable Television Technology and Operations*. Coaxial cable plants developed from the early rudimentary systems to very wide bandwidth coaxial cable distribution systems, carrying a multitude of programming covering entertainment, news, weather, sports, education, and community services. Systems with long trunk runs operating at 400 to 450 MHz upper limit had to use power-doubling amplifiers and/or feed-forward types to reach the ends of the system. The placement of nodes or distribution points fed from super trunks was one method used to limit cascaded amplifier problems. This type of cable plant employed a large number of amplifiers (actives) along with signal couplers and dividers as well as the required number of connectors.

Problems with system leakage, noise, signal distortions, and high power consumption made for very expensive plant requiring a lot of maintenance. Microwave radio links were also employed to share head-end and satellite receiving systems with a number of signal distribution points. Technical personnel had to have all the necessary technical skills needed to service and maintain a variety of equipment. And along came fiber optics, which for many systems was just what was needed. For most systems, replacing the trunk system with optical fiber shortened amplifier cascades and provided a superior signal to the signal distribution nodes. System leakage was reduced and power consumption was reduced as well as amplifier cascade noise and distortion components. Technicians now found that more training was required to learn the installation, maintenance, and testing procedures for the optical fiber section of the cable television system. The next chapter is a study in fiber-optic communications.

CHAPTER

5

Subscriber
Installation
and Terminal
Devices

The Subscriber Drop

The subscriber drop unfortunately has not had the attention and consideration it deserves from many cable operators. The nature of the cable television industry is partly responsible for poor and improper subscriber drop installations. At system turn-on or activation, the marketing and sales effort produces many subscribers ready to be installed. Most system operators do not have enough technical personnel to install the initial influx of subscribers, making it necessary to engage the services of outside-drop installation contractors. Traditionally, drop installation contractors go from system to system installing subscribers for various cable system operators. Unfortunately, supervision and quality control checks are often not done, allowing poor installations to occur. In many cases, the discovery of drop problems occurs long after the drop installation contractors have departed. Many systems find that a lot of correctional work has to be done to the drop installs to bring them up to proper specification. In many cases, this correctional work is unforeseen and unbudgeted, causing unplanned expenses.

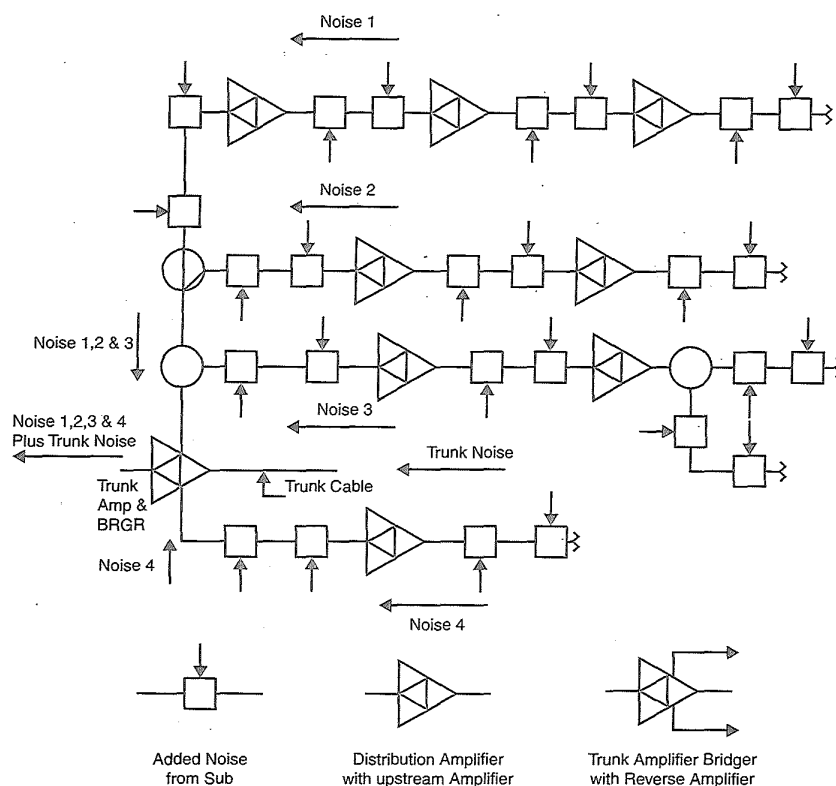
Early Installation Techniques

The aging of the drop install has been a problem for many cable operators. The improvement in the design of the "F"-type connector has undergone several major changes. The latest type, mentioned in Chapter 1, "Introduction," is of high quality and with proper installation should last a lot longer than the first generation connectors. Often, if subscribers have not complained of drop problems or no service calls have been performed, the original installation will be in operation even to this day. Systems expanding subscriber services by activating the upstream signal path quickly discovered serious noise and interference problems.

One of the main contributors is the subscriber drop. Many subscribers move the outlet from room to room, adding more cable and connectors to the internal system. The quality of components as well as the subscriber's work is usually substandard and contributes to return system noise. For many systems, the upstream frequency band is five to 40 MHz and is referred to as the subsplit return band. Noise generated in the subscriber drops are coupled into the upstream reverse amplifier cascade. Noise and interference is coupled at feeder-splitting points back into the bridging amplifier reverse module. Combining again takes place at trunk-splitting points and is transmitted through the return amplifiers to the head-end. An example is described in Figure 5-1.

Figure 5-1

Up-stream noise combining



Since the early days, drop cable has undergone many improvements. Probably the most significant improvement has been in the increased shielding effectiveness. Present-day, high-quality drop cable has an aluminum foil wrapping the polyethylene foam dielectric and is covered with two woven aluminum braids woven over each other, followed by the polyethylene jacket. This type of cable gives a 90-percent shielding that amounts to over 100 dB of isolation. Essentially, this type of cable has three shields and is often called tri-shielded cable. Systems that experience significant noise build-up will have to budget a work project to prepare the return band for upstream signal transmission. A measurement of noise in the upstream band should be made at the head-end at points arriving from each trunk branch. Once a particularly noisy branch is identified, testing back along the trunk to the splits should be done to identify which, if any, is the most noisy point. Many systems have found that reworking the drops in the system using 90-percent shielded drop cable, new "F" connectors, and

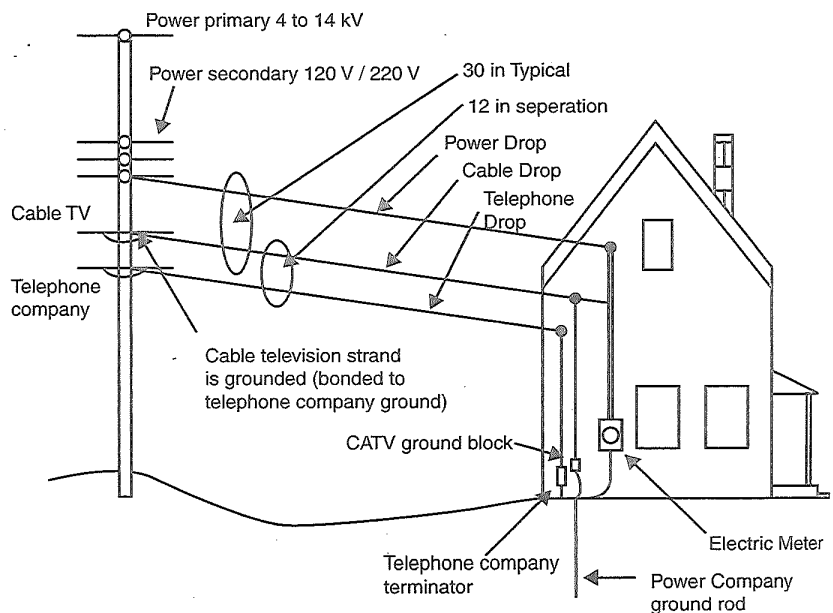
exterior drop hardware drastically improves the noise and ingress on the return path. Troubleshooting maintenance techniques in testing is covered in more detail in the next chapter.

Methods Subscriber installations in many communities of single family homes or duplex apartments are aerial drops. The aerial drop, exposed to the elements of weather, deteriorate quicker than many underground drops. This is mainly due to wind, rain, ice, and snow stressing the drop cable at the points of connection, that is, both the utility pole and the house. An aerial subscriber drop is shown in Figure 5-2.

Also the effects of lightning can cause drop problems. If a lightning strike is close by, a power surge can take place or the cable grounding point can be affected to the point of burning or scorching the connector at the entrance point. If a signal outage occurs, then a service call will be requested by the subscriber and the cable technician will properly repair the problem. The effects of wind and the weight of ice can cause the cable to lose its concentricity, resulting in the increase in return loss and the shielding effectiveness of the cable. Systems experiencing such drop cable problems usually change to messenger cable, which gives added strength and support to the drop.

The material used in the subscriber drop was similar to that used by telephone companies, but it did not take the cable industry long to develop

Figure 5-2
Subscriber cable drop



hardware and drop components that were more appropriate to its own requirements. The ease of installation with high-quality materials is the criteria that many progressive cable operators use regarding their subscriber drops. However, many cable operators have elected to use low-cost materials and poor drop installation contractors, which result in poor service to subscribers and a flood of service calls.

Since the points of connection at the utility pole and the subscriber's home are where the stresses appear, the hanging devices are extremely important. At the utility pole line, a span clamp is used to clamp to the steel messenger strand and provide a captive hook to fasten the drop wire. The drop cable containing its own steel messenger wire can be used by simply wrapping the stripped back steel strand tightly wrapped with several turns around the span clamp hook. For RG-6 cable that is non-messengered, a pre-formed galvanized wire forming a loop with the ends tightly twisted can be used as a cable grip. The twisted ends are coated with a sand-encrusted, semi-soft plastic covering. This device is referred to as a pre-form, which in its larger sizes is used in pole line construction, connecting strand together with splices or dead-end loops. The small version used in subscriber drops is the best method where non-messengered drop cable is used.

At the subscriber's house, a screw hook is used to fasten the drop cable. In many instances, installers fail to place this hook firmly into solid wood, causing the hook to pull loose and the drop to fall. This hook provides proper length to pass through the trim board into a corner timber. A twist in the hook eye prevents a cable using a pre-form to swing out of the hook. At this hook the cable is looped out and either stapled down the trim board or fastened with cable clamps down the side of the house to a grounded entrance block. This block contains a grounding connection for the ground wire connected to a grounding electrode. The grounding electrode is the electric utility ground rod or connecting wire to this rod. Cable operators should never loosen any clamps connecting wires to the ground point or rod. The proper technique is to add another ground clamp to the rod for the cable ground wire to attach. Drop connections for aerial drops are shown in Figure 5-3a and b for both the system point of contact and the subscriber's home. Proper hanging and placement of the drop wire is directly related to the life of the installation. The drop wire should not be drum tight nor hang too low. A good rule of thumb is to allow a sag at midpoint of one foot per 100 feet of drop cable at a temperature of 70° F. This is essentially eye-balled according to how the drop wire sags over the drop length. Most competent installers can often estimate the sag by how hard it is to pull the drop tight.

Some drop contractors and cable company installers often work as a single-person crew. Single-person installers often start in the house by placing the

Figure 5-3a
At house

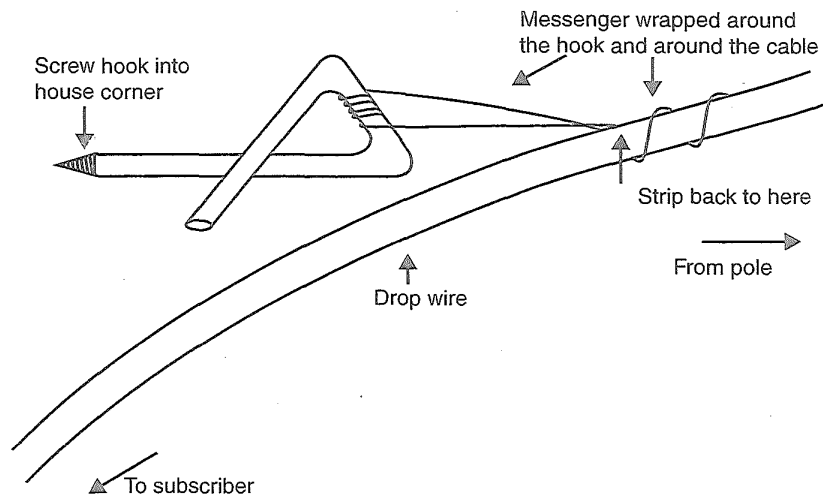
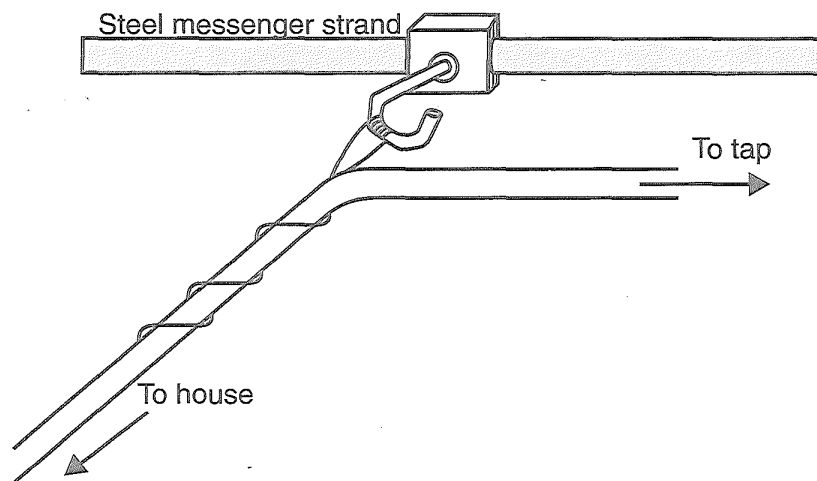


Figure 5-3b
At tap

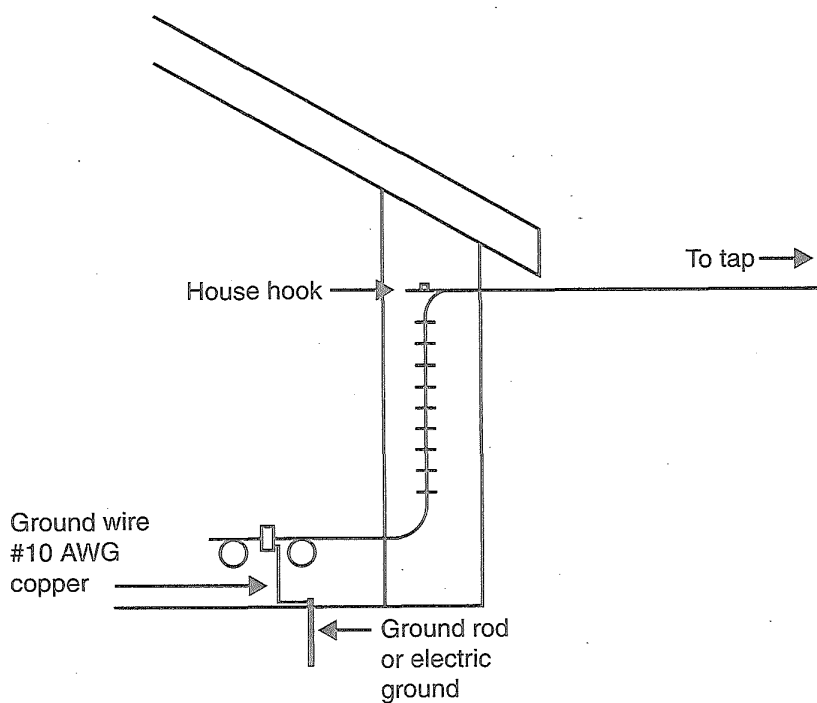


cable supply reel outside, drilling the access hole into a basement area or crawl space beneath the house, and threading the cable to the terminal location. At the terminal location, a connector is attached and the cable is fastened to the house timbers by either staples or cable slips. Staples should be either Monel or stainless steel composition. Cable clips are usually plas-

tic fastened by aluminum or stainless steel nails. Once the initial inside work is finished, the installer can roll the excess cable back on the reel. The installer should now place the ground block near the hole where the cable comes through, install a connector on the cable, and connect to one terminal on the ground block, making a loop as shown in Figure 5-4.

Now the messengered drop cable is used for the actual hanging wire. The messenger wire should be separated from the cable a length approximately equal to the distance from the ground block to the house hook. Now a connector is installed and connected to the ground block through a similar loop and stapled or fastened to the side of the house with cable clips. The messenger wire is formed around the house hook and then back around the cable, previously shown in Figure 5-3a. At this time, the installer moves the cable supply reel to the pole, climbs the pole, and cuts a portion of the messenger loose, separating enough to wrap around the span clamp placed on the strand convenient to the tap port. Tensioning of the drop is done at this time by pulling the messenger wire through the hook and wrapping it around the hook and the drop wire, as previously shown in Figure 5-3b.

Figure 5-4
Aerial installation
detail



A connector placed on the drop wire and connected to the tap completes the pole work.

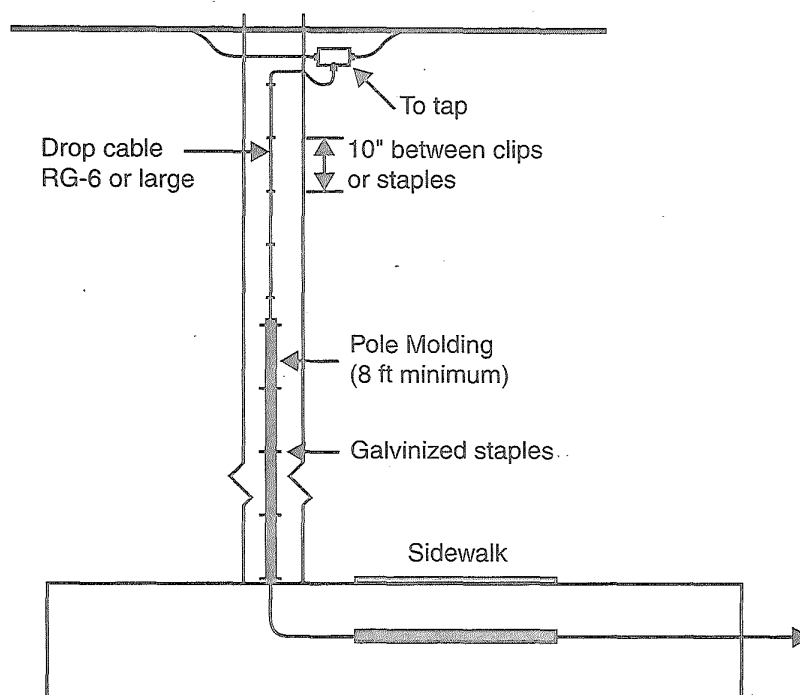
If not already completed previously, the installer should ground the ground block to the power ground electrode. If no ground is readily available, a cold water pipe exposed as a hose connection can be used, providing there is a direct connection to a metallic municipal water supply. In many instances, a subscriber can be connected via a plastic supply pipe or a driven well water supply. If it is necessary to drive a separate ground rod, a 5/8-inch copper clad rod is preferable to other types. It is often helpful and informative if the wiring inspector is consulted by the cable operator's technical department concerning any local codes and grounding-bonding practices.

Underground Methods Many cable systems today are opting for underground or buried plants, following the trend of many telephone companies. Installing plant underground minimizes the problems of traffic hazards as well as weather hazards. In many urban residential subdivisions, it is required that all utility services be placed underground.

Underground drop wires have been in existence for a long time. Early underground drops were placed in a slit in the ground made by a flat spade or lawn edger. As the need appeared for faster and deeper drop installations, a variety of powered machines appeared. Present-day machines plow drop cables to depths of a foot at rapid rates approximately 15 feet per minute through average soil conditions. Soft, wide tires allow these small cable plowing machines to cross lawns with a minimum of restoration problems. At the pole, the cable is connected to a tap port and is either stapled or fastened to the utility pole. The bottom eight to 10 feet should be covered with a molding to protect the cable at ground level. A correctly installed drop cable at the pole is shown in Figure 5-5.

Usually the cable is plowed from the base of the pole to the house where the ground block is located. If a sidewalk is located between the pole and the house, a section of steel or "PVC schedule 40" conduit should be pushed under the sidewalk. An appropriate amount of cable should be left at the pole to reach the tap port and dressed to the pole. At the house, enough cable should be left to form a drip loop at the ground block. Direct burial drop cable with a flooding compound should be used for such underground drop installations. For present-day cable systems offering service in the 800-MHz range, only RG-6 or larger 75-ohm drop cable should be used. A typical underground drop connection at the subscriber's house is shown in Figure 5-6. Many new home developments are served by underground cable plant in pedestals or vaults, requiring drops to be placed underground as well.

Figure 5-5
Underground drop
shown at pole



Splitting & Coupling Most cable subscribers require more than one cable outlet and many subscribers have a whole interior cable distribution system. Often new homes are pre-wired using either a loop-through or home-run system. Both types are shown in Figure 5-7. Multiple outlets require either signal splitters or directional couplers to distribute the input signal level among the outlets. Some cable operators feel that the loop-through system saves cable and hence cost, while other operators think that more directional couplers offset any savings in cable costs. The choices are not often clear-cut and often depend on the expertise of the installer technician. However, ideally all subscriber outlets should have nearly the same signal level and enough levels to operate the TV set or converter terminal. Some cable operators offer pre-wire services to developers or subscribers with costs rebated at activation. Cable operators doing it this way have some control over the quality of the installation. Unfortunately, many subscribers elect to extend or rework their interior cable distribution system using inferior components often improperly installed. This results in

Figure 5-6
Underground drop to
subscriber's house

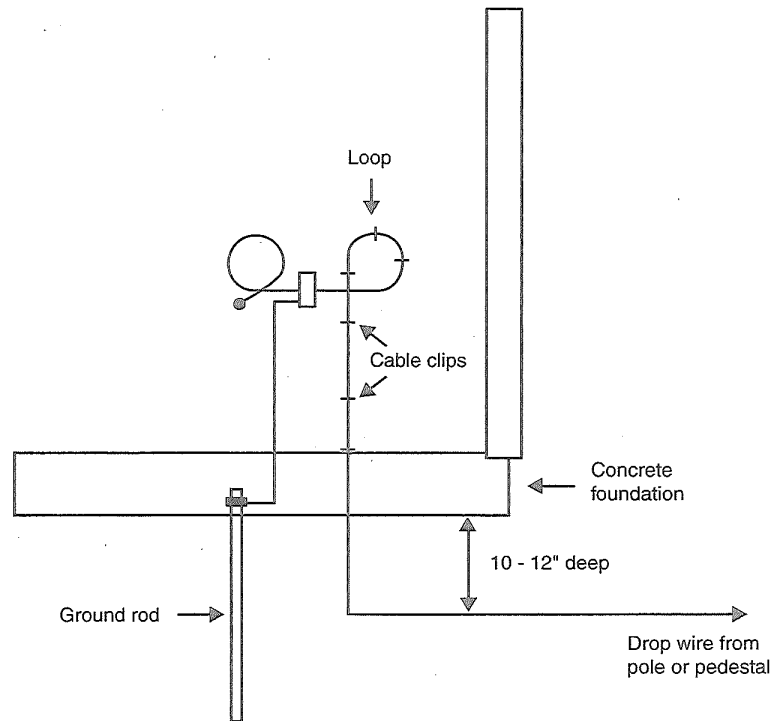
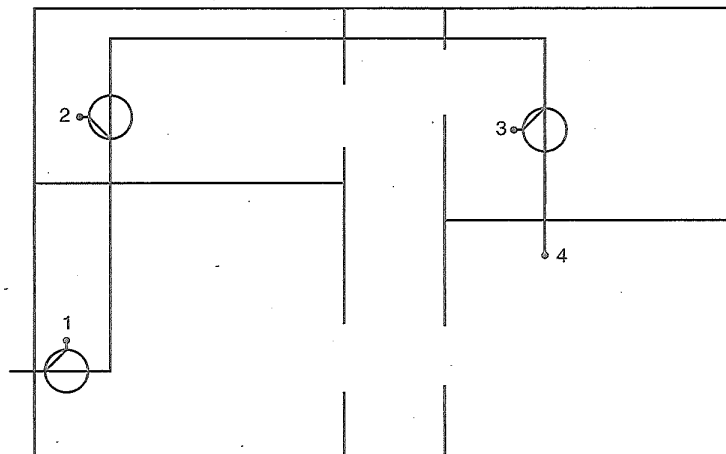
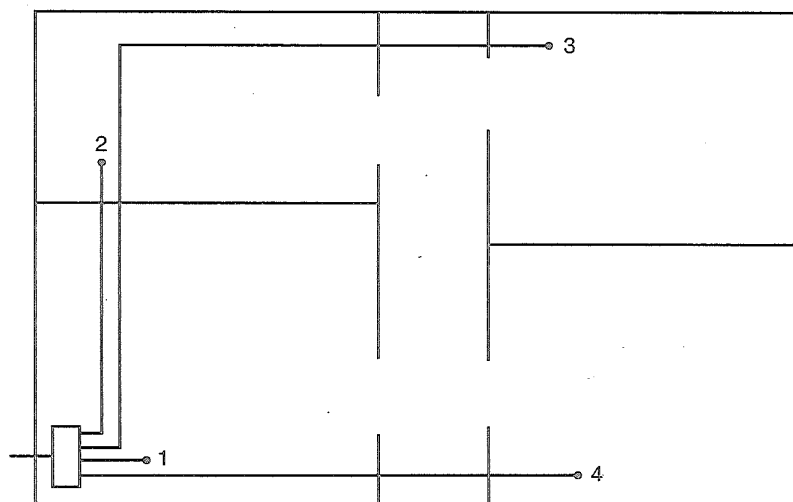


Figure 5-7a
Four-outlet loop-
through using
directional couplers



4 Outlets Loop Through using Directional Couplers

Figure 5-7b
Four outlets homerun
type using one four-
way splitter

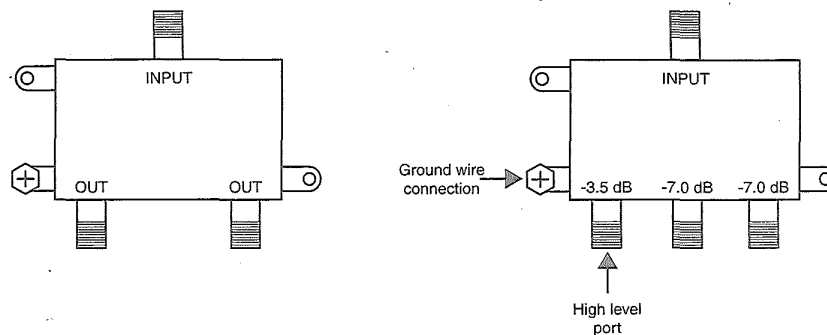


poor service, for which the cable company is blamed. Systems that have a large number of poor subscriber installations can experience noise and ingress problems in the upstream return path.

Most subscribers elect for usually two or three cable outlets covering a family room, bedroom, and possibly a kitchen-dinette area. Signal-splitting can often be conveniently made outdoors where the drop connects. Many vendors of drop equipment offer two, three, and four outlet outdoor signal-splitters with a grounding connection. This type of connection does not need a separate ground block since these devices are fitted with a ground wire connection. A splitter of this type is shown in Figure 5-8.

Grounding and Bonding Two of the most important aspects of the subscriber installation are grounding and bonding. Proper grounding and bonding protects the drop as well as the subscriber's equipment from the effects of lightning. In lightning-prone areas, often soil conditions do not provide adequate ground conduction necessary for a good earth ground. Often several ground rods screwed end to end are necessary to obtain a decent earth ground. Some suburban residential areas have a metallic water supply system, which can act as a good ground for the telephone electrical and cable system. Electrical utilities are grounded using ground rods or to the water system, provided it is metallic. However, the proper ground electrode for cable systems is the electrode used by the utility companies, which is either a rod or water system.

Figure 5-8
Outside grounded
splitter

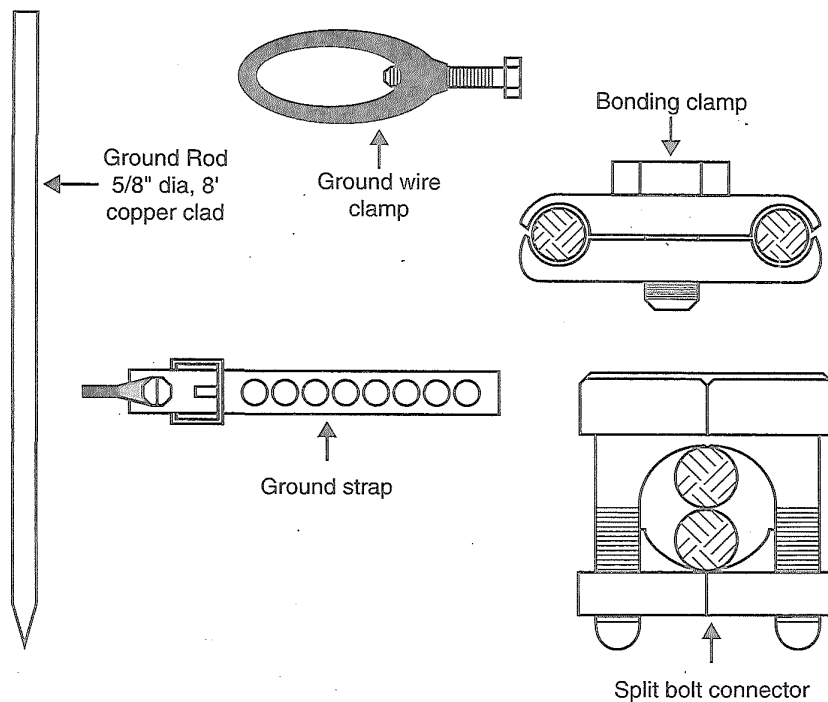


Ground conduction is usually measured using a device called a “megger.” Two copper ground rods are separated a few feet apart and are driven to the same depth. The instrument is connected to each ground rod, which then places a difference of potential between the ground rods measuring the resulting current. The ground resistance is read from the instrument scale or can be calculated by dividing the test voltage by the measured current. Most instruments of this type provide a direct reading of the ground resistance between the two rods. The proper measurement of ground conduction is the ratio of the ground resistance to the distance between the rods given in ohms per foot. Often the desired result is 25 ohms per foot. If need be, a longer rod or a rod with a larger diameter may be necessary to achieve this result.

The conductor size used to ground the cable service to the grounding electrode is #14 AWG copper wire. This size is the minimum that should be used and many cable operators use a larger size of #12 AWG solid copper conductor with PVC insulation. The insulation offers some added strength to the wire and protection against corrosion. This type is usually readily available from either cable drop supply vendors or electrical supply companies. Such suppliers usually carry ground clamps for a cold water pipe connection or ground rod clamps and split bolt connectors that are used to connect to another ground wire. Several type of these devices are shown in Figure 5-9.

The usual installation procedure for proper grounding is to determine how the power neutral is grounded. If the power ground electrode is a driven ground rod, a ground rod clamp can be placed on the rod and a #14 or large copper wire can connect the cable ground block to the clamp. If the top of the rod is not available, the cable ground wire can be attached to the power ground wire using a split bolt connector or the wire can be connected to the power metallic entrance box using a spade lug and screw.

Figure 5-9
Ground system
devices



At the poles, any bonding is done using bare #6 AWG copper wire using strand-bonding clamps connected to the cable system strand and the telephone company strand. The bonding procedures and specifications for an aerial plant are usually spelled out in detail in the pole attachment agreement between the cable operator, the telephone company, and the power company. Proper grounding and bonding is extremely important to the cable operator as well as the utilities. The cable operator's technical staff should instruct all cable installers on proper procedures for grounding and bonding the distribution plant and the subscriber's home.

Several large *multiple system operators* (MSO), as they are known in the cable industry, are presently or will be offering telephone service in the near future. It is common knowledge that telephone systems carry their own power. Thus, a loss of electrical power does not cause the telephone system to fail. Cable systems offering telephone service are going to have to provide all signals and power to the telephone terminal in the subscriber's home. This means the drop cable is going to carry electrical power through the install cable path to the telephone set. For proper protection of power

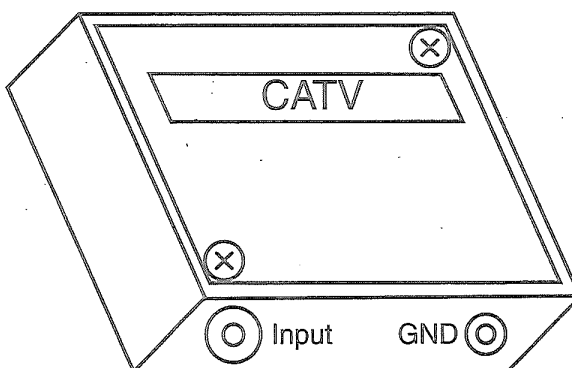
surges, a surge protector will have to be placed at the ground block location. This necessitates a cable communication entrance box housing to contain the ground block, surge suppressor, and possibly a signal splitter. Fortunately, several vendors offer a variety of such products to the cable industry. Also, for subscribers not taking any services requiring the upstream path, the placement of a filter in this cable entrance box will prevent any ingress and noise getting into the return system. The use of an entrance box makes a nice-looking install and keeps the drop equipment and connectors protected from the weather. This adds to the system reliability necessary to compete with other communication providers. An example of an outside residential entrance enclosure is shown in Figure 5-10.

Quality Control Most cable system operators perform little or no quality control checks on subscriber installations, regardless of whether they were done in-house or by a drop contractor. The reason, most likely, is due to extra cost and expense. This, of course, is a serious mistake that can come back to haunt the cable operator. After all, it is the drop connection that is providing the service the subscriber is paying for.

Two schools of thought exist for checking out subscriber drops. One is to have a technician follow around the installation crews and check on every drop. This is, by far, the most comprehensive as well as the most expensive. The second method is to spot-check the drop installation. Finding a problem with the quality of the work will point the finger to the crew responsible, which is the type of check preferred by most cable operators.

The first thing a cable operator must do to obtain quality drop installations is to make sure that the installers, either in-house or contractors, have proper training in the way the cable operator wants the work to be per-

Figure 5-10
Cable
communication
entrance enclosure



formed. This includes specifying the drop material and the methods for doing the job indicated by the cable operator. Cable operators should start quality control checks on the installations either on a complete or a spot-check basis soon after the work commences. This will nip any problem areas in the bud.

The cable operator should keep accurate records recording which drops were inspected as well as noting any problems and comments. Forms for these inspections can be developed and printed in tablets. The inspector can then check the items listed as being per drop material and installation, as shown on the form. At the end of the day, the inspection form information can either be filed or entered into the technical file computer database. By using a hand-held computer in the field at each inspection location, data pertaining to the inspection can be entered directly. This information can be accumulated on diskette and either filed or compiled in the technical database. The cable industry should, if it not already has, obtain appropriate software to aid in proper record keeping. Essentially, the information entered on a form or on a computer should be the same. An example of an inspection form is shown in Figure 5-11. Whichever method is used, the quality control information at initial turn-on is important for maintaining the drops and subscribers' service, as well as studying the effects of the drops as the system ages.

Drop Aging & Deterioration

The aging of the subscriber's drop is definitely related to costs and expenses. It is a known fact in the cable television industry that high-quality drop installations may cost slightly more in the beginning but will definitely last longer and be relatively problem-free. Unfortunately, most plants and equipment under the conditions of weather and seasonal temperature changes deteriorate with age. Thus, the outside subscriber's drop has essentially a limited life span that varies with the quality of the initial installation. For many systems, the life of a drop installation varies from eight to 12 years, which is also often the length of the system financial loan. Therefore, the buyer of a 10-year old system should evaluate the condition of the subscriber drops before making any financial offer. A new prospective owner of a 10-year old system should plan on replacing the drops as part of an overall system upgrade.

Corrosion & Moisture Metallic corrosion due to moisture is one of the concerns of drop deterioration. Iron rusts, aluminum oxidizes, and copper turns green; all are forms of corrosion. Metallurgists have studied the

Figure 5-11
Installation quality
control checklist

INSTALLATION QUALITY CONTROL CHECKLIST

OUTSIDE

ADDRESS OF SUBSCRIBER:

STREET NAME / NO. _____

AERIAL / U.G. _____ LENGTH OF DROP (EST) _____ FT

MIDSPAN / DIRECT _____ DIRECT POLE TO HOUSE (Y/N) _____

GROUND ELECTRODE:

SEPARATE ROD Y _____ N _____

ELECTRIC UTILITY:

GROUND ROD _____ CONDUIT _____
METER BOX _____ WIRE _____

WATER PIPE CONNECTION _____

GROUND CONNECTIONS:

TIGHTNESS _____ WIRE PLACEMENT _____

GROUND BLOCK "F" CONNECTORS:

APPROVED CONNECTORS (Y/N) _____ WEATHER BOOTS (Y/N) _____
USE OF SEALING COMPOUND (Y/N) _____

SIGNAL LEVEL AT GROUND BLOCK:

LOW CH # _____ HIGH CH # _____

INSIDE

NUMBER OF SPLITS _____ SPLITTERS / COUPLER _____

SIGNAL LEVEL AT FARTHEST POINT FROM GROUND BLOCK:

LOW CH # _____ HIGH CH # _____

CONVERTER / SUBSCRIBER MODEM:

TYPE USED _____

SUBSCRIBER'S COMMENTS ON SERVICE AND WORK DONE:

NAME OF TECHNICIAN _____ DATE _____ TIME _____

effects of metal corrosion and the effects of dissimilar metals in contact. Throughout the years, the metal industry has provided corrosion-resistant metal alloys for manufacturers to make metal components for the communications industry. Aluminum alloy amplifier, tap, and passive housings are

all used in the outside cable plant. Ground blocks are made of aluminum alloy and are fitted with plated brass cable connections. The latest version of the "F" connector is made of high-quality metals and contains an interior O-ring to keep moisture from entering the connector from the cable end. The manufacturing industry has responded with high-quality drop installation components and cable systems should use them. Splitters and couplers are made from corrosion-resistant aluminum alloys and some use stainless steel. All are sealed against outside moisture. Still, if some of these enclosures are not hermetically sealed, moisture from the outside air can carry moisture to the inside and water can condense, causing interior corrosion. If such components can survive 10 winters of rain, ice, and snow, this amounts to a 10-year life span for drop components. As subscribers move from one location to another causing subscriber churn, a cable operator should use this disconnect/reconnect cycle to upgrade the drop installations.

Drop Cable Stress Damage The continual stretching and relaxing of drop cable in the wind causes it to deteriorate. Also, temperature effects of expansion and contraction add to the wear on the drop cable. Since this cable is a transmission line with a 75-ohm characteristic impedance, it must retain its characteristics or the signal it carries can deteriorate. The center conductor must remain in the exact center and an equal distance from the shield, thus maintaining its coaxial condition necessary to maintain its characteristic impedance. If the source (driving) and the load impedance are matched at 75 ohms, the cable has to be 75 ohms over the frequency range in order to maintain the matched condition. Most of us know when the load or source impedance is different than the cable characteristic impedance, a mismatch occurs and signal reflections take place. These reflections cause the subscribers' pictures to have ghosts, which is an objectionable picture impairment.

Hanging cable is usually kept at a prescribed sag, which allows for expansion and contraction. The cable grips mentioned previously called pre-forms keep the hanging stresses from affecting the connector at the tap, which can also be accomplished by using messengered drop cable. Still, the nearly constant motion of aerial cable can cause stress cracks in the outer jacket, allowing water and moisture to enter and start corrosion of the cable shielding. Proper attention of the drop at a service call can head-off problems later on. A few more minutes spent by a competent service technician observing the condition of the drop installation should be a company rule.

Lightning & Electrical Effects The effects of lightning on subscriber drops can be catastrophic. Systems that usually have lightning problems

are in what is known as lightning-prone areas. Various sections of the United States are more prone to lightning than others and a map showing different areas' rates of thunderstorms is shown in Figure 5-12. Such a map is called an isokeraunic map. Obviously, the southern and southeastern states are more likely to experience lightning problems. Often these same locations have sandy soil and maintaining a good earth ground is a problem concerning not only the cable operator, but also the electrical utility company and the telephone company as well. As previously discussed, a good ground at the ground block is necessary to protect the subscriber's property as well as the cable service.

Cable drops that have been affected by a direct or nearby strike can exhibit scorching around the ground block. If this happens, the ground wire and connections should be checked and possibly the whole ground block and the associated cable connectors should be replaced. All the subscriber outlets should be tested for signal levels in case some of the components found in the splitters or directional couplers have been burned out. Sometimes the effects of lightning show up at a later date, resulting in a call back. Since the subscriber's television sets and converters are connected to the power system and power system ground, proper ground bonding should be done to protect any currents due to lightning to flow in the home wiring. How this

Figure 5-12
Annual thunderstorm
days

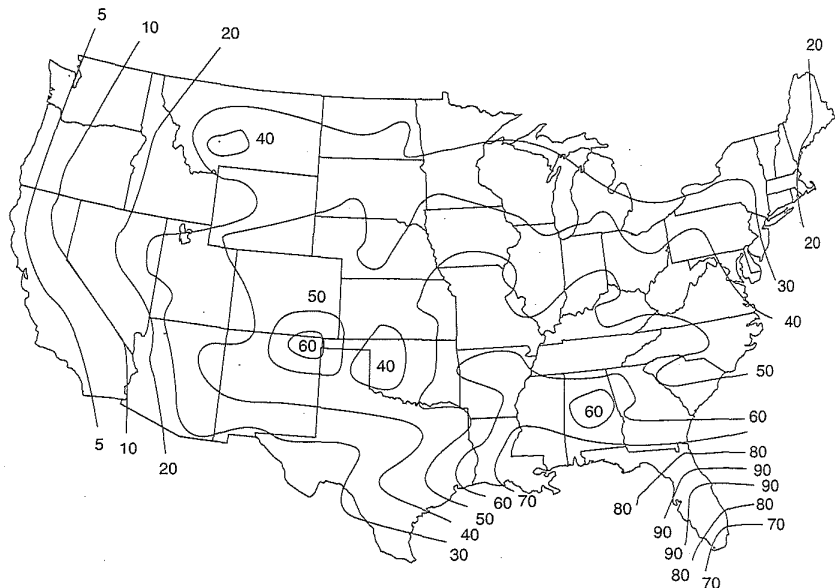
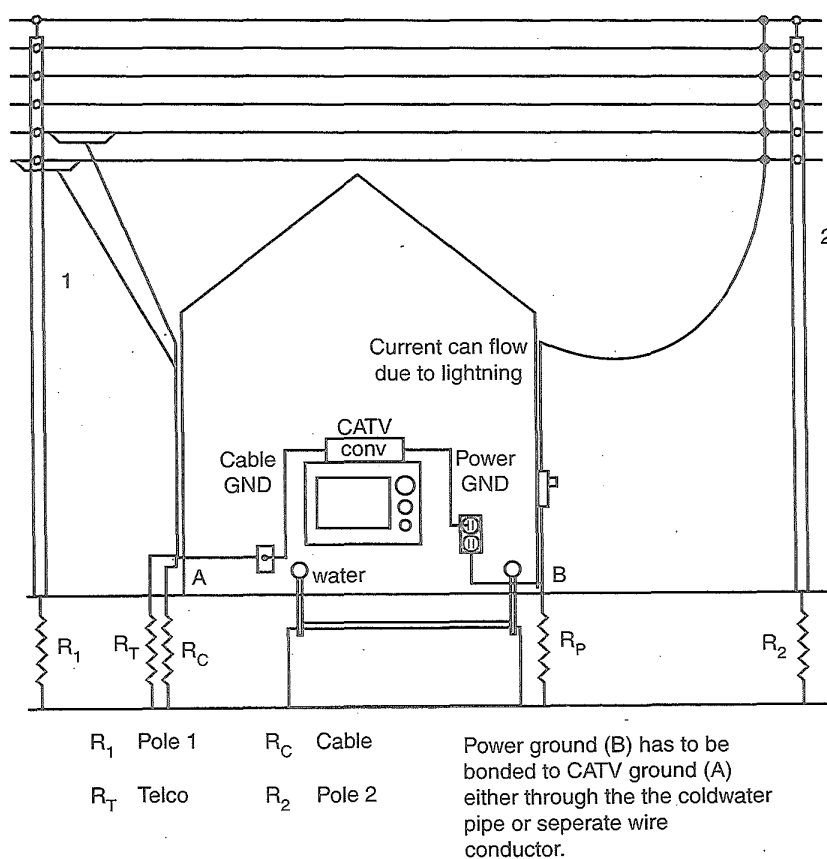


Figure 5-13

Ground bonding for protection from lightning



happens can be shown by considering Figure 5-13. The 75-ohm to 300-ohm matching transformer required by older television sets is easily affected by lightning and often has to be changed after particularly heavy lightning. In many cases, these transformers protect the set itself by "taking the hit."

Subscriber Converters

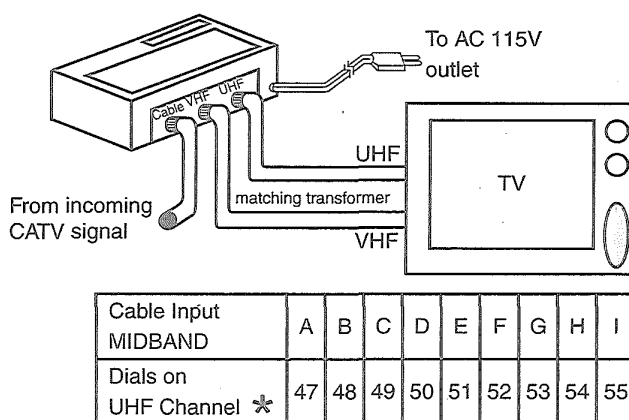
Subscriber converters have been through many generic versions throughout the years. The first use for a subscriber converter was to enable a television set to tune to a channel it could not receive otherwise. Early television sets were basically a 12-channel set offering channels 2 through

13. When the FCC opened up the UHF television band, television sets made after that time became fitted with a UHF channel selector, while earlier television set owners had to purchase a separate UHF converter. As mentioned earlier in Chapter 1, cable operators provided 12 channels on a cable system with an upper frequency limit of 220 MHz. UHF stations were translated down to the band of 108 MHz to 170 MHz, which could carry nine mid-band television carriers. The translation was done at the cable system head-end by adding these nine channels to the already established 12 channels, which gave a system 21 total channels. A subscriber converter then translated these channels back up to UHF channels to be selected on the television set's UHF converter.

Midband Block Converters

This type of UHF converter was considered a mid-band block converter that translated a block of mid-band frequencies up to UHF channels. It used a fixed frequency local oscillator that transformed the mid-band channels up to UHF standard channels. Such a converter is shown in Figure 5-14. Converters of this type had no controls or On/Off switches and remained active as long as the plug was in the wall. When pay or premium programming became available, the mid-band channels were used to carry this service.

Figure 5-14
UHF block converter



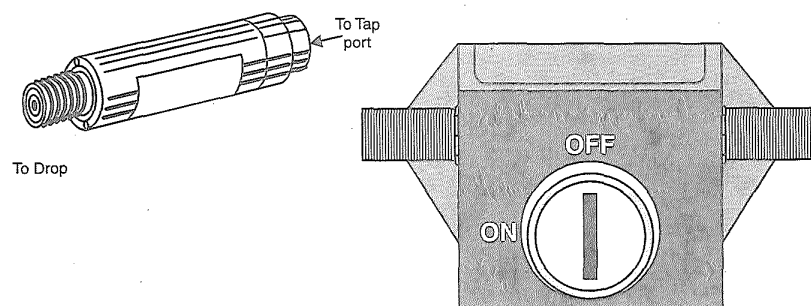
* Other channels may be translated to other UHF channels.

Usually one or two premium channels were grouped together and separated from the UHF channels by a blank channel. This converter also enabled the use of a remote control, yet when this type of converter was in use, few television sets had remote controls.

Signal Security Methods When premium or pay channels were added to cable systems, some means of preventing the unauthorized use of them was needed. Since a cable system grouped pay channels consecutively, a signal-delete filter (trap) was devised to remove the premium channels from the subscriber's drop. This trap appears in a barrel-type configuration with a male connector on one end that was screwed into the tap port, and the drop was then connected to the other end. Since this type of trap was used to deny the premium channels from a subscriber, all non-takers of the premium channels had use of this trap.

For systems without many premium programming subscribers, a lot of traps were used. This, of course, was an expensive choice. A so-called "fix" to this situation was to insert an interfering carrier into the premium channels that would cause intentionally severe picture distortions. Placing a sharp notch filter in the drop, usually at the subscriber's tap port, would delete the interfering carrier, allowing clear reception of the premium channels. This type of trap was known as a positive trap. It was needed only by premium subscribers and thus a system with few premium subscribers did not need to use many units and would pay few expenses. If 50 percent of a system's customers were premium subscribers, it would make no difference in costs, regardless of which method was chosen, since both the positive and signal-delete types of traps cost nearly the same amount of money. Figure 5-15 shows what these traps look like.

Figure 5-15
Signal security taps



A system audit of the number of active premium subscribers a system had could easily be performed by viewing the system taps on a drive-by basis. Eventually, people stealing the premium service were found by systems who discovered a look-alike dummy trap that did not function. Cable television supply vendors quickly developed a trap security shield that enclosed the trap and required a special tool to either install or remove it.

Signal Quality Factors The use of converters and traps did have some affect on picture quality. The block converters could drift a bit and thus the subscriber would have to readjust the fine tuning on the television set. Leaving the converter powered constantly helped the drift problem. Television sets at the time had poor noise figures for the UHF tuner and since the block converter translated the mid-band channels to the UHF tuner, slight snow could be seen by subscribers viewing these channels. Negative-type traps had to be made with steep edges above and below the pass band so as not to remove any picture information from adjacent channels. Positive traps, while removing the interfering carrier, would often remove some side-band signal components, causing some amount of picture impairment.

The Selectable Converter

An improvement to this process was the selectable converter that allowed all program selections to be made by the converter channel selector. The channels selected on the converter were converted to either channel 3 or 4 on the VHF channel selector. This selectable converter began many disagreements between the consumer electronic industry and cable operators. Unfortunately, many of these converters were poorly made and caused cable systems a lot of trouble.

Converter Operation The selectable converter was placed between the cable drop and the television receiver and appeared on top of or near the television set. Some of these converters also had a fine-tuning control that often confused the subscriber with the television tuning system and the converters. Mistuning problems caused many cable operators a lot of expensive subscriber service calls.

Signal Security Signal security with this type of system was done as before by either positive or negative traps. Actually, this type of converter did little for the cable operator and in many instances caused more problems than it solved.

The Programmable Converter

The electronic programmable converter was introduced when signal scrambling methods were developed. Signal scrambling of the premium pay channels was done at the cable system head-end and it was the job of the converter to unscramble the signals at the subscriber's television set. The first generation of this type of converter used a "PROM" chip with the decode logic permanently burned into its circuits. Cable operators could order from suppliers the pre-programmed chips or could program their own using a PROM programmer often referred to as a PROM burner. It did not take long for private chip operators to appear, allowing unauthorized use of a cable system's premium pay channels. This converter contained the descrambling circuits that would descramble channels authorized by the PROM chip. Again, channel selection was performed by the converter and translated to a low VHF channel, usually channel 3 or 4. This made the television set's remote control useless. Since many subscribers wanted remote control, cable converters with remote controls became available. Now subscribers had two remote controls and one was useless. The relationship between the consumer electronics industry and the cable system operator as well as the subscriber had not improved.

Signal Scrambling Signal-scrambling methodology was in the beginning quite simple and effective. Removing the horizontal synchronization pulse caused television sets to lose synchronization, destroying the picture, yet the audio signal was not disturbed. In order to remove the horizontal synch pulse, the scrambling circuit had to find it. This is actually quite easy circuit-wise and at each sync pulse interval a circuit shorted it out to ground level (zero volts), thus removing its presence from the video signal. Actually, this was done at the video IF inside scrambler at the head-end. In the converter, the reverse procedure was performed on command from the programmed PROM, thus restoring the synch pulse. One of the problems with this converter is that they could "walk," meaning it could be moved to another location and be used with any television set.

Prom Programming The authorization and security control remained with the PROM. By using the PROM programmer, some cable systems tried to use more complicated authorization codes. Still for many systems, the signal thieves just became more clever. Many manufacturers of cable converters worked with cable operators to try and keep up with the theft of service problems.

The Addressable Converter

The addressable-type converter seemed to solve some of the security problems. With the addressable converter, an exclusive code for the subscriber was programmed into its PROM. Each converter had to have this code refreshed at predetermined intervals or the converter would shut down and cease operating. Also, the information for the selected channels to decode was transmitted on the downstream data signal along with the address data. This data stream was transmitted just above the FM band using FSK-type modulation. This type of converter allowed a subscriber to call the cable customer service office and order a change in pay service. The controlling computer, which was also usually a part of the billing system, would select the subscriber code and change the decode instructions for the desired channel and delete any others from the service. This, of course, was a savings to the cable operator because a technician did not have to physically go to the subscriber's home since the changes would be made in the office.

Converter Initialization Converters shipped from the factory to a cable operator had to be initialized before being placed in service at a subscriber's home. This initialization process could be done quickly if the control computer was fitted with a bar code reader. If not, the converter identification number could be entered on the keyboard. Manufacturers of addressable converters supplied the control software to the cable operators. This software was used to program the controlling computer, which in turn controlled the converters out in the field. During the initialization process, the subscriber's identification code number was assigned and added to the database along with the coded information, as the premium services was also added. The control computer sent converter activation refresh signals along with premium channel selections to the addressable converters on a rotating basis. The more premium subscribers a system had, the longer the refresh time cycle. If a converter was unplugged or disconnected from the cable system, it would automatically shut down and become dormant. This prevented passing the addressable converter around or, as they say, the box from walking. Still, actual signal security depends on the level of signal scrambling or encoding methodology.

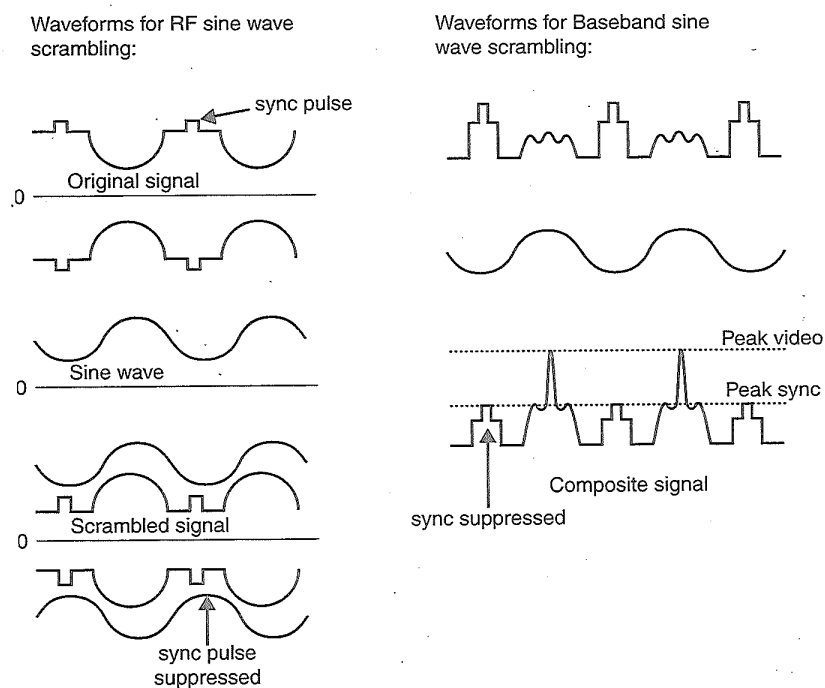
Scrambling Descrambling The more complex the video/audio signal is scrambled, the more secure the signal becomes. Also, the more complex the scrambling technique becomes, the more complex the descrambling method becomes. It should be obvious that the added complexity of the whole process results in a higher cost. The two basic categories for signal scram-

bling are analog and digital. Analog methods are often regarded as soft and digital as hard, referring to the signal security level.

As discussed previously, signal-trapping methods using either positive or negative traps are regarded as soft signal security. This signal could be simply defeated by removing the negative trap (usually at the tap) or replacing it with a look-alike dummy trap. The positive trap, which was needed to remove the interfering carrier, could be placed at the subscriber's TV set. Such traps are easy to obtain and can often be found advertised in the rear merchandising pages of electronic hobby magazines.

A more secure analog method is the sync suppression method, which can be done at R.F. or on the baseband video signal. The horizontal sync pulses are essentially suppressed a sufficient amount, causing the television set to lose its horizontal hold. Both methods use a 15.73-KHz sine wave signal to suppress the sync pulse, which is shown in Figure 5-16. In order to unscramble the signal, the reverse process is used. Essentially, a sine wave at the same frequency is used to restore the synchronizing pulse and the brightness level. This sine wave is transmitted on the cable system either just above the FM broadcast band on any FM carrier or is transmitted as

Figure 5-16
Two forms of sine wave horizontal sync suppression methods



part of the FM audio signal on the scrambled channel. The unscrambling process is performed in the set-top converter usually just after the input converter circuit. The restored or unscrambled picture is then converted to the set-top output frequency, usually channel 3 or 4.

Another analog horizontal sync suppression method is the gated sync suppression method. This method can be used for R.F., I.F., or baseband video. In the R.F. and I.F. methods, pulses with the same timing as the horizontal sync for the channel to be scrambled are applied to the RF or IF signal suppressing the sync pulse, usually at six to 10 dB.

Some signal scramblers have the amount of suppression selectable at 0 (no suppression) 3, 6, or 10 dB. Suppressing the horizontal synchronizing signal fools the television receivers sync separator circuits, thus preventing the set to lock the picture.

Other methods provide increased signal security because they further change the video signal. A form of video inversion can be successfully used in conjunction with the gated sync method. Inverting the video signal (between horizontal sync pulses) interchanges the white and dark portion of the picture, resulting in an image like a film negative. Unscrambling is more complicated and hence more expensive to cable operators who feel the higher level of security is worth it. The Zenith Corporation used this type of signal scrambling on their Z-TAC system.

Since digital television is nearly upon us, digital encoding with its highly complex encrypting methods will offer cable operators extremely high levels of signal security. Two methods of digital encoding are line shuffling and line dicing. It should be obvious that at the mention of lines we are referring to NTSC video lines of digitized video signals. By now, one should realize that digital television will not be simply digitized NTSC video signals, but it will be digital data generated by digital television cameras and equipment. Therefore, the security coded algorithms that will be encoded at the point of transmission and decoded within the digital television receiver are yet to be developed. Signal security will also be a high priority that will protect the signals from unauthorized viewing.

The Interactive Subscriber Terminal

The subscriber modem as the set-top box will be a smart converter and will be addressed by the cable system head-end controller, which will respond with an acknowledgement. In essence, the head-end controller will correspond with each subscriber's cable modem using digital handshaking protocols. Cable Labs have recommended that the cable television industry

adopt the open cable standard. This specifies a standard set-top unit that subscribers can purchase at local electronic outlets. A conditional access device will be available from the cable operator and will control access to the premium program offerings. The set-top and the conditional access device will require both software and hardware components. As yet, actual units have not been delivered to date. Cable systems that are converting some program channels to digital are going to need this type of system. Digital television channels will be available from video discs and in the near future from HDTV. The major vendors of equipment such as *General Instrument* (GI), *Scientific Atlanta* (SA), and Phillips will have digital set-top units available. Signal security will also be digital with many possible algorithms for a very high level of signal security.

Terminal Initialization Some initialization procedure will, of course, be necessary and may vary among manufacturers. Digital set-tops will contain memory chips and *reduced instruction set chips* (RISC) to perform the error checking and the required signal processing and signal authorization functions. Ideally, the subscriber will purchase the converter of choice at a local electronics store and call the local cable operator to order initialization. The data stream channel will initialize the converter, programming it to provide service on the desired channels ordered. Most cable systems gearing up for digital television service will also be activating the upstream channels and digital communications between the head-end and the converter will take place. Some systems may elect to use a telephone modem in place of the upstream cable service. The use of software information to control and initialize the subscriber converter is similar to that of activating a cell phone.

Encoding/decoding The channel encoding/decoding work will be done by the subscriber converter, as always has been the case in the past. However, the process will be done in the digital domain since the digital converter will have the smart chips programmed by the initialization process. Interchanging packets of data by some algorithm will encode the video and audio data stream. The decode procedure will have the preprogrammed recipe to reshuffle the packets into the correct sequence. Digital encoding and decoding offer the cable operator the highest level of signal security.

Program Ordering/Pay/view Digital television service over cable should produce extremely clear pictures and CD-quality multichannel sound. Digital television is being used in the *direct satellite system* (DSS) where decoding is done in the receiver. The service is ordered at the time of purchase and after installation and activation the authorization codes and

decode algorithms are sent on the data channel from the up/down satellite link. Essentially, digital signals will be done in the same manner on cable systems. Digital set-tops will operate by sending the authorized and decoded digital data stream to the digital television set. In the mean time, the set-top will convert the data stream to a NTSC-type television signal required by present-day television sets. This process is similar to that done by the DSS satellite receivers. For a premium programming service, a conditional access module containing the decode algorithm will either be a plug-in chip module or a software module download. In the future, the television receiver will most likely contain all of the decode circuitry and a set-top converter/modem will be unnecessary.