CABLE TELEVISION: A GUIDE TO THE TECHNOLOGY

PREPARED FOR THE NATIONAL SCIENCE FOUNDATION

CARL PILNICK
WALTER S. BAER

R-1141-NSF
JUNE 1973

Rand
SANTA MONICA, CA. 90406
The research described in this report was supported by the National Science Foundation under Grant GI-32107. Reports of The Rand Corporation do not necessarily reflect the opinions or policies of the sponsors of Rand research.

RAND REPORTS ON CABLE TELEVISION PREPARED FOR THE NATIONAL SCIENCE FOUNDATION

This series of reports was prepared under NSF's grant to the Rand Communications Policy Program. It includes the following titles, each preceded by the series title Cable Television in the printed copies:

R-1134-NSF, A Summary Overview for Local Decisionmaking, by Walter S. Baer.
R-1139-NSF, Citizen Participation After the Franchise, by Monroe E. Price and Michael Botein.
R-1140-NSF, Applications for Municipal Services, by Robert K. Yin.
R-1143-NSF, Uses in Education, by Polly Carpenter.

A special bibliography of Rand publications on cable television is available on request. Information on Rand publications may be obtained by writing to: Publications Department, The Rand Corporation, 1700 Main Street, Santa Monica, California 90406.
CABLE TELEVISION RESEARCH AT RAND

The Rand Corporation began its research on cable television issues in 1969, under grants from The Ford Foundation and The John and Mary R. Markle Foundation. The central interest at that time was federal regulatory policy, still in its formative stages. Rand published more than a dozen reports related to that subject over the next three years. This phase of Rand's concern ended in February 1972 when the Federal Communications Commission issued its Cable Television Report and Order.

The Report and Order marked the end of a virtual freeze on cable development in the major metropolitan areas that had persisted since 1966. It asserted the FCC's authority to regulate cable development, laid down a number of firm requirements and restrictions, and at the same time permitted considerable latitude to communities in drawing up the terms of their franchises. It expressly encouraged communities to innovate, while reserving the authority to approve or disapprove many of their proposed actions.

The major decisions to be made next, and therefore the major focus of new cable research, will be on the local level. These decisions will be crucially important because cable television is no longer a modest technique for improving rural television reception. It is on the brink of turning into a genuine urban communication system, with profound implications for our entire society. Most important, cable systems in the major markets are yet to be built, and many cities feel great pressure to begin issuing franchises. The decisions shortly to be made will reverberate through the 1980s.

Aware of the importance of these events, the National Science Foundation asked Rand in December 1971 to compile a cable handbook for local decisionmaking. The Handbook\(^1\) presents basic information about cable television and outlines the issues a community will face. It is addressed to citizen group members, local government officials, and other people concerned with the development of cable television in their communities.

Cable television embraces such a host of political, social, economic, legal, and technological issues that any single book on the subject is in danger of being shallow at best and pretentious at worst. Consequently, the Handbook is intended as an introduction and guide to these issues, which are explored separately in the series of companion reports listed inside the front cover.

All decisions about cable television, of course, must be made in light of present technology and the likely technical developments of the future. This report describes the present state of cable technology, technical approaches to meeting the new FCC requirements for major market cable systems, and the technology for new cable services. Since technical feasibility is linked inextricably with costs, the report also discusses the cost considerations encountered in building a new cable system or expanding one now in operation. It is written at an introductory level for readers without a technical background.

The report identifies a number of problem areas that presently confront the cable industry and local decisionmakers, including expanded channel capacity, technical standards, two-way communications, and system interconnection. These involve complex tradeoffs among technical approaches, economic factors, and the capabilities demanded of a cable system. The report is written to shed some light on the realistic policy alternatives available, but it is not intended as a step-by-step guide to designing the "optimal" system for a community. Specific solutions will require more detailed analysis and the application of technical expertise in each local situation.

* * * * *

The authors are grateful for the constructive comments made on an earlier draft by Edwin Deagle and Victor Nicholson of the Cable Television Information Center, and by Norman Hanunian and Bridger Mitchell of Rand.

They also gratefully acknowledge the support of The John and Mary R. Markle Foundation, whose three-year grant to The Rand Corporation for communications policy studies facilitated completion of this report.
SUMMARY

Cable television is changing from a broadcast redistribution service to one that offers local programming, pay-TV, and a host of potential new services. As a result, cable technology is evolving rapidly to meet new regulatory requirements and market conditions. The main technical differences between "advanced" and "conventional" cable systems include an expanded channel capacity, added facilities for local program origination, equipment to restrict channels for pay-TV or other uses, internal switching and external interconnection capabilities, and the capacity for two-way communications.

Expanded Channel Capacity. Conventional cable systems have carried 12 channels at most. The FCC's requirement for 20 or more channels in the major television markets can be met in three ways: (1) by installing more than one cable, (2) by carrying more channels on a single cable and installing a frequency converter at each subscriber's receiver, or (3) by designing a switched system that sends a selected channel from a local distribution center to the subscriber's receiver. Cable operators in the United States generally choose a dual cable or a converter system, or a hybrid of the two. Eventually, cable-compatible television receivers will obviate many of the current technical problems.

Cablecasting Facilities. The FCC now requires cable systems with more than 3500 subscribers to produce local programming "to a significant extent"; systems in the major markets also must make facilities available for public access programming. Consequently, new cable systems usually design cablecasting studios that are less elaborate and costly versions of broadcast TV studios. The development of low-cost, portable video cameras and tape recorders makes program production possible anywhere in the community.

Restricted Access. Pay-TV is the principal commercial nonbroadcast service that cable systems will offer in the next few years. It requires special equipment to deny pay-TV programs to those who do not want to pay for them, and to record the proper charges for those who do. Field trials of pay-TV are under way in about ten communities, and several others are planned in the next few months.

Interconnection. Although there are no federal requirements for interconnection, sharing or exchanging programming will be important for most major market cable systems. Moreover, cable systems serving large areas generally will require two or more headends. Large-diameter cable or over-the-air microwave is used for multichannel interconnection. A new form of microwave relay, known as Local Distribution Service, has recently been developed for cable interconnection.
Two-way Communications. An eventual two-way capability is required of new major market cable systems by the FCC. Two-way services to home subscribers generally differ from those for institutional users in the transmission capacity and terminal equipment they require. The principal technical approaches to two-way transmission are to install a separate cable for the return link or to carry signals simultaneously in both directions on a single cable. The first presents fewer technical problems but is more costly; field trials to date have tested the second approach. Two-way development is proceeding slowly because of technical problems and high costs.

Whether to write and enforce local technical standards is a vexing problem for most communities. The FCC's technical standards apply only to broadcast television signals and can be satisfied with a picture quality below that received off-the-air in many cities. Most major market cable systems must exceed the FCC standards in order to sell subscriptions. However, a community will find it difficult to write unambiguous, enforceable standards beyond the FCC's minimum, and it must enforce them itself.

Extending a cable system's capacity for new services, or making it more flexible for future expansion, implies a higher initial cost. With the nature and value of new services so uncertain, it is much easier to quantify the added costs than the private revenues and public benefits that will be gained. Moreover, cable operators, government officials, and local citizens are likely to disagree on the present value of future benefits. Resolution of these issues requires analysis of the technical, economic, and service tradeoffs in each local situation.


## CONTENTS

CABLE TELEVISION RESEARCH AT RAND ........................................ iii

SUMMARY .................................................................................. v

Section

I. INTRODUCTION ................................................................. 1
  Cable Television Distribution Versus Broadcasting .................. 2
  How a Basic Cable System Works ........................................ 3
    Towers and Antennas ....................................................... 3
    Headend ................................................................... 5
    Facilities for Local Origination ....................................... 5
    Cable Trunk .................................................................. 7
    Amplifiers ................................................................... 8
    Feeder Cable ............................................................... 9
    Subscriber Taps and Drops ............................................ 9
    Extending the Range of Cable Services .......................... 11

II. COMMUNICATION CAPACITY OF CABLE SYSTEMS .......... 13
  The Basic 12-Channel System ...................................... 13
  Expanded Channel Systems ........................................ 15
    Multiple Cable Systems ............................................. 15
    Systems with Converters ............................................ 17
    Switched Systems ...................................................... 20
  The TV Receiver Problem ............................................. 21
  Comparing Alternatives ............................................... 21

III. CABLECASTING ............................................................... 23
  Studio Facilities ............................................................ 23
  Video Cameras and Tape Recorders .................................. 25
  Mobile Facilities ........................................................... 28
  Program Production ....................................................... 30

IV. INTERCONNECTION OF CABLE SYSTEMS ................. 31
  Forms of System Interconnection .................................... 31
    Internal Interconnection (Subdistricting) ....................... 31
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Interconnection</td>
<td>31</td>
</tr>
<tr>
<td>Networking</td>
<td>32</td>
</tr>
<tr>
<td>Interconnection Techniques</td>
<td>33</td>
</tr>
<tr>
<td>V. TWO-WAY COMMUNICATIONS</td>
<td>35</td>
</tr>
<tr>
<td>Subscriber Services</td>
<td>35</td>
</tr>
<tr>
<td>Institutional Services</td>
<td>39</td>
</tr>
<tr>
<td>Two-Way Transmission Techniques</td>
<td>39</td>
</tr>
<tr>
<td>Two-Way Demonstration Projects</td>
<td>42</td>
</tr>
<tr>
<td>VI. TECHNOLOGY FOR NEW SERVICES</td>
<td>47</td>
</tr>
<tr>
<td>Pay TV and Private Channels</td>
<td>47</td>
</tr>
<tr>
<td>Information Retrieval and Frame Storage</td>
<td>50</td>
</tr>
<tr>
<td>Electronic Mail and Faxsimile</td>
<td>51</td>
</tr>
<tr>
<td>Videocassette Recorders and Cable Television</td>
<td>52</td>
</tr>
<tr>
<td>High-Resolution TV</td>
<td>52</td>
</tr>
<tr>
<td>Institutional Services</td>
<td>53</td>
</tr>
<tr>
<td>Teleconferencing</td>
<td>53</td>
</tr>
<tr>
<td>Video Surveillance</td>
<td>54</td>
</tr>
<tr>
<td>High-Speed Data Transmission</td>
<td>54</td>
</tr>
<tr>
<td>VII. TECHNICAL STANDARDS</td>
<td>56</td>
</tr>
<tr>
<td>FCC Technical Standards</td>
<td>56</td>
</tr>
<tr>
<td>Writing and Enforcing Local Technical Standards</td>
<td>57</td>
</tr>
<tr>
<td>Signal Quality</td>
<td>58</td>
</tr>
<tr>
<td>Reliability and Maintainability</td>
<td>59</td>
</tr>
<tr>
<td>Performance Monitoring and Testing</td>
<td>59</td>
</tr>
<tr>
<td>Problem Areas</td>
<td>61</td>
</tr>
<tr>
<td>APPENDIX: FCC TECHNICAL STANDARDS FOR CABLE SYSTEMS</td>
<td>63</td>
</tr>
</tbody>
</table>
I. INTRODUCTION

Cable television is a communication system that distributes television signals and other information by wire rather than through the air. More than twenty years old, it is just now turning from infancy to adolescence. The changes are only partly technological, but an evolving technology provides the base for cable's economic development and its future usefulness to society.

Cable began as a service to communities with inadequate off-the-air television reception, either because TV transmitters were too far away or because mountains, tall buildings, or other obstacles stood in the direct broadcast path. Cable provided a better television picture and usually more channels than viewers could receive directly off the air.

Today, most of these small towns and rural areas already have cable television. The urban centers and their surrounding suburbs remain as the principal areas of the United States yet to be wired; but because most of these areas already have good broadcast television reception, cable must offer a new range of services to gain subscriptions.\(^1\) Cable has also been slow to penetrate the cities because of regulatory policies of the Federal Communications Commission (FCC). From 1966 to 1972, the FCC prohibited cable systems in the 100 largest television markets\(^2\) from carrying television stations outside their market areas. This ban was partially lifted by new FCC regulations that became effective March 31, 1972. These rules also set up new requirements for major market cable systems, including a minimum capacity of twenty channels, allocation of three access channels, local program origination for systems with more than 3500 subscribers, and some capacity for two-way communications.\(^3\)

Thus, both market factors and new regulations demand that new cable systems be constructed differently from those of the past. Building in additional communications capacity for new services is the principal design change. Before we turn to these developments, however, it will be helpful to review the basics of cable system design.

---


CABLE TELEVISION DISTRIBUTION VERSUS BROADCASTING

A coaxial cable, pictured in Fig. 1, provides an electronic "information highway," no different in principle from a telephone wire or a wireless communication link such as broadcast radio or television. In each case information is sent as a varying electrical signal generally superimposed on a high frequency "carrier."  

![Diagram of a coaxial cable]

Fig. 1—A typical coaxial cable

The higher the frequency of the composite signal (information plus carrier), the more information the system can transmit. All signals lose strength, however, as they travel from the transmitting point—an effect known as attenuation—and high-frequency signals are attenuated more than low-frequency ones. Consequently, there is a practical limit to the range of frequencies ("bandwidth") any electronic communication link can carry over a given distance. Broadcast television stations in the VHF band (channels 2-13) often provide good-quality signals fifty miles from their transmitters if no obstacles stand in the way. Higher-frequency, UHF stations (channels 14-83) usually cover smaller areas. Cable systems are much more limited in range, as discussed in Sec. II.

Cable systems can deliver more television channels, however, since signals on the cable are less subject to adjacent channel interference than are those transmitted through the air. Broadcast television stations must be separated in frequency in

---

4 Information can be carried either as an "analog" signal continuously varying in amplitude (AM) or frequency (FM), or as a "digital" signal composed of a series of discrete pulses. Television sound and picture information now is sent in analog form; digital signals are more appropriate for computer data and messages. The use of digital transmission over the telephone network is increasing rapidly for voice conversations as well as for data traffic.

5 The FCC defines three classes of broadcast signals:
- **Principal City Service**—Satisfactory picture quality expected at least 90 percent of the time for at least 90 percent of the receiving locations.
- **Grade A Service**—Satisfactory picture quality expected at least 90 percent of the time for at least 70 percent of the receiving locations.
- **Grade B Service**—Satisfactory picture quality expected at least 90 percent of the time for at least 50 percent of the receiving locations.

Maps showing Grade A and Grade B contours for VHF and UHF television stations in the United States can be found in the *Television Factbook*, Stations Volume, published annually by Television Digest, Inc., 1836 Jefferson Place, N.W., Washington, D.C. 20036.
a given area; for example, a community cannot receive both channels 12 and 13 over the air. In contrast, a well designed cable system can deliver adjacent television channels without appreciable interference. The abundance of channels, along with cable’s ability to serve areas where over-the-air reception is inadequate, is the present basis of cable’s technical advantage over broadcast television. In addition, cable systems can select audiences for pay-TV or other programs, and can provide two-way response communications from the viewer to the program source. These features are discussed in later sections of the report.

HOW A BASIC CABLE SYSTEM WORKS

Figure 2 illustrates a conventional cable TV system designed to distribute broadcast television programming. Its components include a tower and antennas to receive broadcast television signals, a “headend” to process them and add other signals, and the cable distribution network that carries the signals to subscribers’ TV receivers. Distribution is on a “party-line” basis from a single origination point (the headend), with each subscriber having access to exactly the same programming.

Towers and Antennas

Antennas to receive broadcast TV signals usually are located on one or more high towers. This is because broadcast signals are blocked by the curvature of the earth and are only partially reflected by the atmosphere. Thus, a sufficiently strong signal will be received only where there is an unrestricted line-of-sight path between a TV station’s transmitter and the cable system’s antenna.

Cable systems in rural areas place towers on a mountain top or other high ground. For urban cable systems, the roof of a tall building may be most suitable. The taller the building, the less need for a high tower. Tower heights may vary from 20 to 30 feet for some systems to 100 to 500 feet for others.

A separate antenna is used for each TV station received, so that it may be tuned to the station broadcast frequency and mechanically aligned to pick up the strongest signal. Where off-the-air signals are especially weak, a preamplifier may be used for each channel. This unit is mounted as close to the antenna itself as possible, usually on a mast of the tower, so that it can boost the desired signal before additional noise is introduced.

In areas with few local TV stations, the cable system operator may wish to bring in distant signals to provide his subscribers with a greater diversity of programs. These distant signals would originate from stations too far away to be received directly by an antenna at the cable system’s tower. Consequently, they must be relayed to the cable system’s headend, either by microwave transmission (at frequencies specially licensed by the FCC for this type of relay) or by a large-diameter coaxial cable. The choice depends upon distance, the number of signals to be carried, availability of microwave frequencies, and cost.

* The FCC permits major market cable systems to import 2 or 3 commercial signals. Other cable systems can import more. See Baer, op. cit., or Rivkin, op. cit., for details.
Fig. 2 — A basic cable television system
Figure 3 illustrates distant TV signal relay by a single microwave link, which can cover a distance of 20 to 30 miles. Additional links would be used for longer distances, with each receiving the signal and retransmitting it to the next.

**Headend**

From the antenna preamplifier, if used, each broadcast signal is connected by cable to the headend facility, usually located in a small building near the tower site. For urban systems, this may be an office in the building on which the receiving tower is mounted. The headend contains the electronic equipment necessary to process signals for distribution on the cable network. A variety of functions are required:

- Undesired signals outside the frequency band of each channel must be filtered out.
- Some channels must be "translated" in frequency before being sent through the cable. UHF stations, for example, are converted to an otherwise unused VHF channel so that they can be selected for viewing at the VHF tuner of each subscriber's TV set. VHF stations also may have to be translated because of local interference problems.
- The TV information from distant signals imported by microwave link must be separated from the microwave transmission carrier. This is known as "demodulation."
- Demodulated signals and all video signals that originate within the cable system must be combined with a carrier frequency to match a channel in the standard VHF TV band. This is known as "modulation."
- All signals must be "mixed" or combined into a composite signal, and then amplified before being distributed on the cable. Mixing also includes adjustment for the fact that the higher frequencies will undergo more attenuation losses in the cable and would, unless compensated, emerge as weaker signals. "Equalization," which in effect amplifies high-frequency signals more than low-frequencies, adjusts for the differential losses.

Equipment to perform these functions is available from a variety of manufacturers, with performance characteristics and prices generally very competitive. New cable systems now being planned or franchised, however, will require other kinds of headend equipment now available only in developmental form or, in some cases, not available at all. This includes equipment for private channel viewing, headend interconnection, and two-way communications. Consequently, the complexity and cost of headend facilities for large cable systems are bound to increase in the future.

**Facilities for Local Origination**

In the 1950s, many cable operators began to originate their own programming. The simplest and least costly forms of local origination are the so-called "automated services." For example, a TV camera might be permanently focused on a clock and weather indicator and left unattended. The picture would be sent out over an unused channel of the cable system to provide subscribers with continuous time and weather information. Stock market or news information can be displayed in similar fashion. Equipment now is available that can take the electrical output of a stock or news ticker and convert it line-by-line for video display on conventional TV sets.
Fig. 3—Cable system with distant signal transportation and local origination
According to *Television Factbook*, about one-third of all U.S. cable systems provide some automated services. Many cable operators in small communities contend this is all the local programming they can afford. Other operators, however, have built studio facilities to distribute live, filmed, or taped programs to their subscribers. This requires much of the same equipment—TV cameras, lights, videotape recorders, film chains, and so forth—that TV broadcast stations use. In effect, such local program origination gives cable subscribers another TV station to choose from. The cable industry calls it "cablecasting," as opposed to broadcasting. The main difference is that a cable operator can identify his audience more precisely and, theoretically at least, adapt the cablecast programs to particular local needs or desires. As of March 1972, about 20 percent of U.S. operating cable systems had the capability to provide full cablecasting service over at least one channel.

Cablecasting studios typically use smaller and less expensive TV cameras and videotape recorders than do their broadcast counterparts. They also are more restricted in studio space, set design, lighting facilities for studio audiences, and program production personnel. Today, cable studio facilities range widely in cost from perhaps $10,000 to $25,000 at the low end, to $250,000 to $500,000 for the largest systems. Cablecasting facilities and equipment are discussed further in Sec. III.

Many cablecasting facilities are located in the same building as the headend. When they are, it is easier to connect studio program signals into the cable distribution network. In other systems, origination facilities may be some distance from the headend. A studio should be convenient to those involved in program production, which generally implies a location in the more populated downtown area of a community, while the headend must be close to the receiving tower, whose location is determined by both signal strength and real estate constraints. If the two are at different locations, a separate cable carries cablecast programs from the studio to the headend.

**Cable Trunk**

The main cables that carry signals from the headend are called *trunk* cables. They are usually 1/2 or 3/4 of an inch in diameter, but may be as large as 1 or even 1-1/4-inches. The larger diameter cables are used for longer distances, since they attenuate signals less. They are more expensive, of course, and also difficult to install because they are heavy and less flexible.

Coaxial cables are either strung on utility poles or placed in underground ducts. In an aerial system, the cable operator rents space on existing utility poles, whose number and location usually are adequate for the cable system. However, the telephone or power utility must rearrange its own wires and otherwise make the poles ready for cable installation. Although this process naturally takes time and costs money, cable operators often complain bitterly about undue delays and excessive charges for obtaining their "pole rights," particularly from telephone companies who might be present or future competitors. As one example, the Kern Cable Company of Bakersfield, California described its problems in a letter to the local County Board of Supervisors:

---

The primary factor in Kern Cable’s inability to meet its construction costs budget can be attributed to an unexpected change in Pacific Telephone Company’s policies relative to the attachment of CATV cables to its poles. . . . Whereas rearrangement costs were originally budgeted at $90,000, the final Telephone Company bills totalled $270,000, an unanticipated expenditure of $180,000.\footnote{Letter from Kern Cable Company to Kern County Board of Supervisors, February 18, 1970.}

More recently, the General Telephone Company of California has proposed to double its pole rental rates to cable systems.\footnote{CATV, April 30, 1973, p. 3.} Since obtaining utility “pole rights” and pole rearrangements often becomes a bottleneck in cable system construction, the FCC is currently considering setting federal regulations in this area. The local franchising authority also may want to monitor the negotiations between the cable operator and the utility that owns the poles. Both parties, of course, are obligated to bargain in good faith. But it may also help if the city clearly expresses its interest in a reasonable and expeditious settlement after a cable franchise is awarded.

Many communities today prefer underground utility construction. Where existing utilities already are underground, the cable system operator normally follows the same practice. The cost is two to twenty times that of aerial construction, depending on whether existing utility ducts have enough room to accommodate the new cables, problems of digging in the city streets, the necessity for protecting against water seepage and corrosion, and so forth.\footnote{Gary Weingberg, \textit{Cost Analysis of CATV Components: Final Report}, Resource Management Corporation, Bethesda, Maryland, 1972, provides useful guidelines to the costs of underground cable construction.} As with pole rights, negotiations with utilities for duct space may be difficult and time-consuming.

Since each city has its own network of subsurface ducts, techniques for underground cable installation are less standardized. Amplifiers are often placed in above-ground housings for easier maintenance and repair. The cable itself is accessed through normal utility manholes, usually with difficulty. As a result, routine maintenance and replacement costs, as well as initial construction costs, are much higher in underground systems.

The actual cable construction and installation must conform to a variety of codes and regulations, such as the National Electric Safety Code, Underwriters’ Laboratories standards, state and city building codes, and the practices required by the utility companies from which pole or duct space is rented.

\textbf{Amplifiers}

Television signals are attenuated throughout the cable system. A signal at the upper frequency limit of current cable TV systems will lose about half its power in a 200-foot length of 1/2-inch trunk cable. Consequently, amplifiers must be placed throughout the cable route to build the signal strength back up to usable levels.

Trunk amplifiers are particularly critical components. Each one degrades the TV signal quality slightly, and their effect in series is cumulative. Thus, there is a practical limit to the number of amplifiers that can be cascaded before the signal quality becomes unacceptable. Where cable competes with good off-the-air reception,
the limit may be 20 to 30 amplifiers in cascade, corresponding to a cable run of 5 to 10 miles from the headend.\textsuperscript{11}

Trunk cable distances must be carefully related to the geography of the area served. To minimize trunk runs, many current systems use a "hub" concept, with the headend at the center of a group of trunk cables strung radially like spokes on a wheel. A single hub theoretically can serve a circle of up to 100 square miles, but municipal boundaries and geographic constraints often limit the effective service area to 50 square miles or less. Larger systems require multiple headends.

**Feeder Cable**

When a trunk cable passes a residential street or other area of concentrated subscriber density, a smaller distribution or feeder cable is used to distribute signals from the trunk to that area. Feeder cables are similar in construction to the trunk, but of smaller diameter (0.412-inch is a popular size).

The trunk and the feeder are connected through a "bridging" amplifier, which electrically isolates the trunk to prevent electrical interferences from degrading the trunk signals. "Line extender" amplifiers boost signals within feeder lines so that more subscribers can be served. Since feeder cable is cheaper than trunk, cable systems generally try to maximize the feeder-to-trunk ratio for lowest costs.

Figure 4 depicts an aerial feeder cable installation. The coaxial communications cable is lashed to a steel "strand" or "messenger" cable for mechanical support. A line extender amplifier appears above the lineman's head. Next to it is a "tap" that connects subscriber "drop" lines to the feeder cable.

**Subscriber Taps and Drops**

A small drop cable brings the signals from the closest feeder line to the home TV set. The drop cable is generally 1/4 to 1/3 of an inch in diameter. A coupler, or tap, connects the drop to the feeder cable. Conventional taps offer low resistance to signals flowing from the feeder into the home, but high resistance to reverse signals. This reduces the possibility of interference emanating from subscribers' homes and entering the cable network. Special two-way taps must be used for return communications from the home.

At the subscriber's home, the drop cable may connect to a small transformer that matches the characteristics of the cable to the input of the TV set. Many new cable systems use set-top converters to provide more than 12-channel capacity (see Sec. II). If a converter is employed, the drop cable will connect to its input. The subscriber also may want a switch to connect his set back to a rooftop antenna should the cable system fail.

\textsuperscript{11} Standard trunk amplifiers are designed to be placed about every 1500 feet for a 1/2-inch cable or every 2000 feet for a 3/4-inch cable. A 25-amplifier chain thus corresponds to a cable trunk run of approximately 7 and 9.3 miles, respectively. However, since cable trunk lines generally follow rectangular street grids, the effective radius serviced from a single headend is only about 5 to 7 miles.
Fig. 4—Typical aerial, single-cable installation
EXTENDING THE RANGE OF CABLE SERVICES

Building the conventional, one-way cable system described above typically costs about $60 to $75 per home passed if most of the construction is aboveground. Assuming 50 percent of households subscribe for service, the system’s initial construction cost is $120 to $150 per subscriber. Many CATV systems that distribute only broadcast TV signals have been built for considerably less.

New cable systems in the major markets, however, are expected to provide more than broadcast TV redistribution. The new FCC rules require them to provide 20 or more channels, produce local programming “to a significant extent” if they have more than 3500 subscribers, provide channels for public access, education, and local government services, make additional channels available on a leased basis for pay TV and other uses, and provide the capability for eventual two-way services. As shown in Table 1, most U.S. cable systems offer none of these added services today. Providing them requires new technical approaches and undoubtedly will raise the cost of cable construction above the figure of $150 per subscriber used in the past. The technology for added cable capacities and services is the subject of the remaining sections of this report.

12 About 17 percent of U.S. cable systems had more than 3500 subscribers as of March 1972, according to Television Factbook.
<table>
<thead>
<tr>
<th>Service Category</th>
<th>Type of Communication</th>
<th>Present Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution of broadcast television programs</td>
<td>One-way, headend to all subscribers</td>
<td>Operational on all cable television systems</td>
</tr>
<tr>
<td>Local cablecasting</td>
<td>One-way, headend to all subscribers</td>
<td>Operational on about 20% of U.S. systems; required of all systems with more than 3500 subscribers</td>
</tr>
<tr>
<td>Public access, educational, and government channels</td>
<td>One-way, headend to all subscribers</td>
<td>Operational on a few systems; required of all new major market systems</td>
</tr>
<tr>
<td>Pay TV or private channel programming</td>
<td>One-way, headend to certain subscribers (two-way useful, but not required)</td>
<td>In prototype form on a few systems</td>
</tr>
<tr>
<td>Subscriber response services</td>
<td>Two-way, data response from subscribers to headend</td>
<td>Under field test on a few systems but not yet operational; “technical capacity for nonvoice return communications” required of all new major market systems</td>
</tr>
<tr>
<td>Information retrieval, document delivery, and other &quot;new services&quot;</td>
<td>Two-way data, voice, and video between subscribers and headend, and possibly among subscribers</td>
<td>Under development</td>
</tr>
</tbody>
</table>
II. COMMUNICATION CAPACITY OF CABLE SYSTEMS

The communication capacity of a cable system has been measured by the number of television channels it could deliver simultaneously to subscribers. The earliest cable systems carried 3 or 5. Most systems built in the last decade have had a 12-channel capacity. Since March 31, 1972, FCC regulations require at least 20 channels for new construction in the major markets.

Channel capacity can be somewhat misleading as a measure of the nonbroadcast services a cable system can deliver. More generally, a system's communication capacity is measured by its bandwidth in cycles per second (or in the more modern units of "hertz," abbreviated Hz). Each U.S. standard television channel requires a large frequency bandwidth of 6,000,000 hertz, usually stated as 6 Megahertz, abbreviated 6 MHz. Thus, the FCC's 20-channel requirement actually means a usable bandwidth of 20 x 6, or 120 MHz.

In contrast, telephone channels need only 3000 to 4000 hertz, or 3 to 4 Kilohertz (KHz). Data channels for sending short messages or alarm signals may require only about 100 Hz. A 20-channel cable system thus in principle could carry 30,000 to 40,000 telephone messages instead, or more than one million fire and burglar alarm channels. Certain practical inefficiencies would reduce these numbers, but data messages in 10,000 or more homes could be sent and received in a portion of a single 6 MHz channel.

Technical limitations on channel capacity are set principally by cable amplifiers. Current amplifiers are limited to a usable bandwidth of about 300 MHz. While this theoretically is equivalent to 50 television channels, interferences among channels give a practical limit of about 25 to 35 channels for each cable.

THE BASIC 12-CHANNEL SYSTEM

Most cable systems previously were designed for 12 channels, however, to match the 12 channels of the standard VHF tuner on television receivers (channels 2-13). If a cable carried more than 12 channels, a subscriber could view them only

1 Engineers find it hard to agree on a precise channel limit, since it depends on the signal quality one is willing to accept, the particular amplifier and cable system design, and environmental factors such as the temperature changes the amplifier is subject to. The 25-to-35 channel range represents some upper limit to today's state of the art.
with a special converter attached to the TV set. Using the UHF tuning capacity of
the receiver would not work, because UHF frequencies starting at 470 MHz are too
high for the cable system to carry directly. Television channel frequency assign-
ments are shown in Table 2.

As a result, any UHF station picked up by a cable system's antennas must be
translated in frequency (down-converted) at the headend before being inserted onto
the cable. An otherwise unused VHF channel is the best choice, since subscribers
can then tune it in directly on their TV sets. Thus, Channel 28 might be translated
to the frequency band for Channel 12, if Channel 12 is not broadcasting in that
region, and be viewed by tuning directly to Channel 12.

Some translations are dictated, therefore, by the need for UHF-to-VHF conver-
sion. Still other translations are necessary because of the phenomenon known as
"direct" or "on-channel" interference. In most metropolitan areas, the local TV
broadcast stations provide a strong signal at the antenna connections of TV sets
within 5 to 10 miles even without an external antenna. The receiver picks up this
broadcast signal in addition to the signal delivered by the cable on the same channel.
Because television signals travel slightly slower through cable than they do through
the air, the cable signal arrives a small fraction of a second later than the off-the-air
signal. The tiny difference is enough to cause a "ghost" image on the TV receiver
that can make the picture unacceptable (Fig. 5).

Consequently, if a community has three strong VHF broadcast stations, say
channels 2, 4, and 7, those three channels probably cannot be transmitted on the
cable at their usual frequencies. Instead, they would have to be translated in fre-

<table>
<thead>
<tr>
<th>Channel Number</th>
<th>Assigned Frequency (MHz)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>54-60</td>
<td>Lowest VHF channel</td>
</tr>
<tr>
<td>3</td>
<td>60-66</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>66-72</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>72-76</td>
<td>Not assigned for broadcast</td>
</tr>
<tr>
<td>6</td>
<td>76-82</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>82-88</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>88-108</td>
<td>FM band</td>
</tr>
<tr>
<td>9</td>
<td>108-174</td>
<td>Not assigned for broadcast</td>
</tr>
<tr>
<td>10</td>
<td>174-180</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>180-186</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>186-192</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>192-198</td>
<td>Highest VHF channel</td>
</tr>
<tr>
<td>14</td>
<td>204-210</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>210-216</td>
<td>Not assigned for broadcast</td>
</tr>
<tr>
<td>16</td>
<td>216-470</td>
<td>Lowest UHF channel</td>
</tr>
<tr>
<td>17</td>
<td>470-476</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>476-884</td>
<td>6 MHz per UHF channel</td>
</tr>
<tr>
<td>19</td>
<td>884-890</td>
<td>Highest UHF channel</td>
</tr>
</tbody>
</table>
Fig. 5—Direct signal pick-up interference

quency, and perhaps delivered as Channels 3, 5, and 8. Cable channels 2, 4, and 7 might still be usable for automated services and other nonbroadcast applications, however, where the interference is less damaging to the displayed information.

Large cities such as New York and Los Angeles may have as many as seven local VHF stations. As a result, seven cable channels may be unusable for television re-broadcast, and a 12-channel system, without converters, could not even deliver all the stations the subscriber could receive directly off the air. For major markets, the 12-channel cable system represents only a historical precedent. It is technologically inadequate even without the FCC 20-channel requirement.

EXPANDED CHANNEL SYSTEMS

Expanding channel capacity requires a new cable system design. As illustrated in Fig. 6, the three principal choices are multiple cables, converters, and switched systems.

Multiple Cable Systems

If one cable can deliver 12 directly selectable channels to the TV set, an obvious solution to expanding capacity is to use two or more cables. Figure 6(a) shows two trunk cables, each of which can carry up to 12 signals. The subscriber is furnished
(a) Dual cable system

(b) Single cable system with converters

(c) Switched system

Fig. 6—Three methods of expanding channel capacity
a two-position "A-B" switch (carefully designed for switching at VHF frequencies) and can select which of the two cables is connected to the TV set at any particular time.

This doubles the viewing capacity. It does not address the problem of on-channel interference. If Channel 4 is subject to such interference, it cannot be used for either cable. Consequently, instead of the nominal 24-channel capacity, a community with four strong over-the-air broadcast stations would have only 16 usable channels on a dual cable system. This could still satisfy the FCC's 20-channel requirement, since all 20 channels need not be used for broadcast television, but it may not be what the community wants. One solution is to connect the subscriber's switch directly to the tuner inside his set with shielded cable, but this requires modification of each TV set subject to on-channel interference.

Dual (or multiple) cable systems are obviously more expensive than single cable systems—not twice as much, since the added installation costs are small, but about 50 percent more. This may or may not be competitive with other ways to expand channel capacity and must be examined on a case-by-case basis. The principal advantage of the multiple cable approach is its simplicity. It eliminates converters, which are problem components, and thus makes the system more reliable. The cable can carry signals at standard VHF frequencies selected to minimize interference among channels. Finally, if each cable is designed initially for expanded channel capacity and return communications, a dual cable system doubles the overall capability for two-way or other new services.

Systems with Converters

A converter changes a nonstandard frequency channel to a VHF channel that can be tuned directly on the subscriber's TV set. Some older style converters, called block converters, translated an entire block of 12 channels from a higher frequency range to the standard VHF band. Most present converter systems use tunable converters, shown in Fig. 6(b). In effect, the converter replaces the standard TV set tuner and provides more channel positions. Channels may be selected with a dial like that of standard tuners, a slide lever, or push buttons; Fig. 7 illustrates three current models.

Carrying more than 12 channels on a single cable requires higher quality amplifiers and more careful system design, both of which cost more money. The extra channels in a converter system are carried on the cable at frequencies between channels 6 and 7 (known as the midband) and above channel 13 (known as the superband). The industry today designates nine midband and thirteen superband channels below 300 MHz, as shown in Table 3. If all were usable in addition to the twelve standard VHF channels, a single cable could carry 34 6-MHz channels. Today's converters, however, are designed for a maximum of 25 to 30 video channels in the VHF, mid-, and superbands. Seven other channels below channel 2 (the sub-band) are usually reserved for two-way or other new applications.

The converter changes the frequency of a selected channel to a standard VHF channel frequency that is unused for broadcasting in the community. The TV set tuner is set permanently to that channel, and all selection is performed at the converter. Unlike conventional TV tuners, its input is shielded from off-the-air
Fig. 7—Three types of cable television converters
Table 3
NONSTANDARD CABLE CHANNELS

<table>
<thead>
<tr>
<th>Channel Nomenclature</th>
<th>Frequency (Mhz)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sub-band</strong></td>
<td></td>
</tr>
<tr>
<td>T7</td>
<td>5.75–11.75</td>
</tr>
<tr>
<td>T8</td>
<td>11.75–17.75</td>
</tr>
<tr>
<td>T9</td>
<td>17.75–23.75</td>
</tr>
<tr>
<td>T10</td>
<td>23.75–29.75</td>
</tr>
<tr>
<td>T11</td>
<td>29.75–35.75</td>
</tr>
<tr>
<td>T12</td>
<td>35.75–41.75</td>
</tr>
<tr>
<td>T13</td>
<td>41.75–47.75</td>
</tr>
<tr>
<td><strong>Midband</strong></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>120–126</td>
</tr>
<tr>
<td>B</td>
<td>126–132</td>
</tr>
<tr>
<td>C</td>
<td>132–138</td>
</tr>
<tr>
<td>D</td>
<td>138–144</td>
</tr>
<tr>
<td>E</td>
<td>144–150</td>
</tr>
<tr>
<td>F</td>
<td>150–156</td>
</tr>
<tr>
<td>G</td>
<td>156–162</td>
</tr>
<tr>
<td>H</td>
<td>162–168</td>
</tr>
<tr>
<td>I</td>
<td>168–174</td>
</tr>
<tr>
<td><strong>Superband</strong></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>216–222</td>
</tr>
<tr>
<td>K</td>
<td>222–228</td>
</tr>
<tr>
<td>L</td>
<td>228–234</td>
</tr>
<tr>
<td>M</td>
<td>234–240</td>
</tr>
<tr>
<td>N</td>
<td>240–246</td>
</tr>
<tr>
<td>O</td>
<td>246–252</td>
</tr>
<tr>
<td>P</td>
<td>252–258</td>
</tr>
<tr>
<td>Q</td>
<td>258–264</td>
</tr>
<tr>
<td>R</td>
<td>264–270</td>
</tr>
<tr>
<td>S</td>
<td>271–277</td>
</tr>
<tr>
<td>T</td>
<td>277–283</td>
</tr>
<tr>
<td>U</td>
<td>283–289</td>
</tr>
<tr>
<td>V</td>
<td>289–295</td>
</tr>
</tbody>
</table>

signals. The converter thus completely eliminates on-channel interference, since its output will never be at the same frequency as a strong local station.

However, converters introduce other interference and picture degradation difficulties. Many converters respond inadequately to variations in signal strength and are overloaded by strong input signals. This causes picture distortion. The frequency of the converter oscillator can drift with temperature and time, resulting in inaccurate frequency conversion. Channel selectivity—the ability to distinguish sharply between adjacent channels—is sometimes poor. And because more frequencies are carried on the cable, more interference problems among channels arise.

These problems are due more to an emphasis on low cost in converter design than to intrinsic technical limitations. Converters range in price from $35 to $40 in
small quantities to $25 to $30 in lots of 1000 or more. Since a converter is needed for each TV set, a $30 unit cost may represent 15 to 20 percent of total system capital investment. Consequently, the pressures for low-cost converter design are great. Initial cost savings, however, may be outweighed over a few years by added service calls and subscriber complaints. Still, the set-top converter is today the most popular approach to providing a minimum 20-channel capacity. Even dual cable systems may need a converter to utilize channels subject to direct interference.

Switched Systems

Switched systems provide a completely different approach to expanded channel capacity by placing channel selection outside the subscriber’s home, as in Fig. 6(c). The two principal switched systems under development are the Ameco DISCADE and the Rediffusion systems. Both bring signals from a headend to switching centers that serve from twenty to several hundred subscribers. Two separate wires or cables run from the switching center to each subscriber receiver. One wire carries subscriber requests to the switching center, and the other returns the selected television signal.

Since each subscriber has his own link to the center and receives only one program at a time, a single, low-frequency band (perhaps 4 to 10 MHz) suffices to carry all programs. If a subscriber requests Channel 2 (normally 54 to 60 MHz), the signal would be down-converted at the switching center to 4 to 10 MHz before being sent to his receiver. Other channels would be similarly down-converted. The major advantage of this technique is that attenuation is less at these low frequencies, so that a smaller and cheaper coaxial cable, or even a twisted-wire pair, can be used for signal distribution to the home.

At the subscriber’s home, a fixed-channel, tunerless converter translates the 4 to 10 MHz signal to a standard unused VHF channel. Since the same one-channel conversion is made every time, the converter can be a relatively simple device.

Switched systems are simple in concept and have advantages for certain applications. Their big disadvantage is the quantity and complexity of cabling they require. The switching centers service a relatively small number of subscribers, necessitating many centers for a large community. Moreover, each TV set requires a separate set of cables or wires to the switching center. In crowded urban areas, the cost of switching centers may be high and the cost of laying the necessary wiring underground may be prohibitive. One recent study estimated the Rediffusion system cost to be 50 percent more than that for a conventional, dual cable system.

For smaller communities, where not too many switching centers are required and construction is mostly aerial, switched systems may well be attractive. They have not as yet, however, become a significant factor in current cable operations in the United States.

---


THE TV RECEIVER PROBLEM

None of the above techniques is an obvious "best solution" to the expanded channel problem. Systems with multiple cables eliminate converters, but do not prevent direct interference. Converters solve the direct interference problem completely, but introduce new possibilities for interference and picture degradation. Switched systems obviate both the direct interference and the converter problems, but seem too cumbersome and expensive for major market operations.

A principal design problem is that all cable components must be compatible with conventional TV receivers, which are today the weakest links in most systems. TV sets are designed to use signals received off the air, not from cable. They generally have poor selectivity, since adjacent broadcast channels are never assigned in any area, and therefore receivers need not have sharp tuning on one channel only. For all practical purposes, the 12-channel VHF tuner is really a 7-channel device under broadcast conditions. The UHF tuner has been added (generally as an afterthought to meet the FCC requirements for UHF reception capability) as a separate device, with a different tuning method and performance characteristics. Shielding is inadequate to prevent strong broadcast signals from being picked up at the input stages of the set, even without an external antenna, and sometimes inadequate to prevent signals from being radiated out from the receiver.

Logically, a cable-compatible receiver could be designed that would ease the above problems and lower receiver costs as well. It would have a multichannel tuner built in (eliminating the need for a separate converter) and better input shielding (eliminating on-channel interference). Although TV set manufacturers are developing cable-compatible models, mass production must await agreement on standards and the emergence of a larger market of cable subscribers—perhaps 10 to 15 million households.

When special receivers are available, cable operators may want to lease them to subscribers as part of their regular cable service. Many existing cable franchises prohibit the operator from leasing or servicing TV sets, usually as a result of pressure from local TV retailers and repairmen. They argue that such leasing would give the cable operator an unfair competitive advantage. The operators contend that TV set leasing not only is fair, but also allows them to guarantee better quality reception and expedites the development of new services. Communities might well strike a middle course by neither forbidding TV set leasing in the cable franchise, nor permitting the operator to require receiver leasing as part of his overall service. The franchise also might permit the operator to make TV set modifications (as, for example, by connecting the cable directly to the tuner inside the set) where necessary to improve reception.

COMPARING ALTERNATIVES

Until cable-compatible receivers are available, a community's choice generally will be among a dual cable system, a converter system, or a hybrid of both. Table

---

4 Some consecutively numbered VHF channels are not really adjacent in frequency, as shown in Table 2. Channels 4 and 5, or 6 and 7, can be assigned in the same area.
4 compares cable distribution costs per mile for several one-way system designs based on recent quotations from equipment suppliers (costs for systems with two-way transmission capability are shown in Table 10). Costs are also shown on a per-subscriber basis, assuming 40-percent penetration in each case.

Table 4

COST COMPARISON OF ONE-WAY CABLE SYSTEM DESIGN OPTIONS

<table>
<thead>
<tr>
<th>System Characteristics</th>
<th>Cost per Mile, Aerial Cable Distribution Plant</th>
<th>System Cost per Subscriber, 40% Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single cable, 12 channels</td>
<td>$4500-5000</td>
<td>$120-135</td>
</tr>
<tr>
<td>Single cable with converters, 20-30 channels</td>
<td>$5500-6500</td>
<td>$190-210</td>
</tr>
<tr>
<td>Single cable with converters, 20-30 channels plus shadow trunk</td>
<td>$6500-8000</td>
<td>$210-250</td>
</tr>
<tr>
<td>Dual cable, 12 channels each&lt;sup&gt;b&lt;/sup&gt;</td>
<td>$6800-7500</td>
<td>$190-205</td>
</tr>
<tr>
<td>Dual cable, 20-30 channels each, with converters</td>
<td>$7800-9800</td>
<td>$250-300</td>
</tr>
</tbody>
</table>

<sup>a</sup>Assumes 100 homes per mile, converters at $35, dual cable switches at $4, headend costs of $10 per subscriber for 12-channel system, $15 per subscriber for other systems.

<sup>b</sup>Minus channels unusable due to on-channel interference.

One current hybrid approach is to install a single cable with converters, plus a second, "shadow" trunk—that is, an extra trunk without amplifiers or other electronic components. The shadow trunk is available when the demand for more channels or new services requires it. The shadow-trunk adds about 20 percent to distribution plant costs.

The other general approach is to build a full dual cable system—dual trunk, feeder, and drop lines—with converters where necessary. A dual cable system with converters may cost 30 percent more than a single-cable system and perhaps require a dollar a month greater subscription fee, but it provides more inherent capacity for future expansion. Whether this added flexibility is worth the extra cost is a question for each community to decide.<sup>5</sup>

<sup>5</sup> Unfortunately, the immediate and future benefits from additional capacity are much harder to quantify than the costs of providing it. Communities must therefore consider the specific ways in which added capacity will be used. For further discussion, see Carl Plinich, Cable Television: Technical Considerations in Franchising Major Market Systems, The Rand Corporation, R-1197-NSF, April 1973, and other reports in this series.
III. CABLECASTING

Most cablecasting today takes place in the cable operator’s studio, which, as mentioned in Sec. I, typically is a compact, less elaborate version of a TV broadcast studio. However, the development of low-cost, portable video cameras and tape recorders makes program production possible anywhere in the community. The easy availability and use of this equipment is responsible for much of the current interest in community program origination, or public access.1

STUDIO FACILITIES

Figure 8 shows, in block form, the major electronic equipment in a cablecasting studio that can produce live programs or distribute those already on film or videotape.

Live programming begins with at least one video camera that converts visual images into video electronic signals in a standard broadcast TV format. Two or more cameras give a more interesting balance among close-up, distance, and angle shots. At the same time, microphones convert the sound information into audio electronic signals. The video and audio are then connected into an array of “signal conditioning” equipment that performs three principal functions:

1. Mixing the audio and video in the right proportion.
2. Amplifying the signals to a level high enough for distribution.
3. Locating the audio and video carrier frequencies with respect to each other in conformance with broadcast TV standards.

A control console, usually located in an adjacent room, permits an operator to select which camera or microphone is on at any particular instant, and to vary audio and video levels for the best combination.

The combined signal, known as the “composite video,” is then sent to a VHF modulator-amplifier. This component translates the video frequency band (0 to 6 MHz) up to a VHF channel that can be tuned in by a TV set. (For example, the

cablecast program could be carried on Channel 3's frequency band, 60 to 66 MHz, if this channel is not used for broadcast signals. A cable subscriber would then view the program by turning his VHF tuner to Channel 3.

The outgoing signal is then amplified and sent through the cable network to subscribers. As described in Sec. II, cablecasting signals are combined at the headend with broadcast signals received off-the-air and those imported from distant cities. All signals are mixed and transmitted simultaneously, with a separate 6 MHz frequency band for each channel.

Many cablecast programs are transmitted from previously recorded tape or film. With a video camera and tape recorder, the cablecasting studio can tape programs, edit them, and play them back to subscribers at a later time. Most studios have two or more videotape recorder/player units, partly for backup in case one fails, but also to be able to reproduce (dub) a taped program by playing back from one and recording on the second.

A "camera chain" is required for programs that are on film strip or slides. This is basically a film or slide projector coupled to a special video camera. The projector will project the photographic image onto a high-intensity internal screen which is then scanned by the video camera. The optical image is converted into a video electronic signal, and then sent to the signal conditioning equipment in exactly the same way as a signal from a live or taped program.

Studios also require a variety of support equipment such as lights, camera dollies, microphone booms, power supplies, and television monitors. The total equipment cost can vary from a few thousand dollars for the simplest black-and-white installation to several hundred thousand dollars for a fully equipped color studio. Table 5 lists the costs for equipment packages offered by two representative manufacturers. The Audiotronics package represents a "very small" studio, while the RCA equipment is in the "small-to-medium" cost range. The cost of a "large" studio can easily reach $250,000 to $500,000 even without mobile equipment.

VIDEO CAMERAS AND TAPE RECORDERS

Video cameras and recorders deserve special comment, since they will often be used by nonprofessionals outside the cable operator's studio. Basically, a video camera combines parts of a motion-picture camera with an electronic scanning device. As in a film camera, a lens focuses an image and projects it on a plane inside the camera housing. This plane is actually the screen of an electronic "pickup" tube, which scans the image a point at a time and converts the shadings of light into a varying electrical signal. The signal is then converted into the form required to meet broadcast TV standards.

Two kinds of pickup tubes, the "Image Orthicon" and the "Vidicon," have been used in most cameras to date (the "Plumbicon," developed by North American Philips, has recently begun to offer competition to the Vidicon). The Image Orthicon is more sensitive and can operate at low light levels, but is relatively expensive. The Vidicon is cheaper and has a longer operating life, but requires more light. Table 6 lists the key characteristics and costs of both tube types.
Table 5  
REPRESENTATIVE STUDIO EQUIPMENT COSTS

<table>
<thead>
<tr>
<th>Audiotronics</th>
<th>RCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Micropak&quot;</td>
<td>&quot;Maxipak&quot;</td>
</tr>
<tr>
<td>1 monochrome video camera</td>
<td>2 monochrome video cameras, with view finders and 2 zoom lenses</td>
</tr>
<tr>
<td>1 video tape recorder, monochrome</td>
<td>1 video tape recorder, monochrome, with electronic editing</td>
</tr>
<tr>
<td>1 video switcher</td>
<td>1 video switcher</td>
</tr>
<tr>
<td>1 control monitor, 16-inch</td>
<td>1 control console</td>
</tr>
<tr>
<td>Cables, mike, tripod</td>
<td>Cables, 2 mikes, tripod, dolly, pedestal</td>
</tr>
<tr>
<td>$2,000</td>
<td>$6,500</td>
</tr>
</tbody>
</table>

"Economy Monochrome TV Studio Package" |
2 monochrome video cameras |
1 film system, monochrome |
1 video tape recorder, monochrome |
1 video switcher |
1 control console |
Cables, tripods, mikes, stands, etc. |
$21,000 |

"Color-Convertible Monochrome TV Studio Package" |
2 monochrome video cameras, color convertible |
1 film system, monochrome |
1 video tape recorder, monochrome |
1 video switcher |
1 audio mixer |
1 control console |
Cables, tripods, mikes, stands, etc. |
$37,000 |

"Medium Color TV Studio Package" |
3 color video cameras |
1 color film system |
2 video tape recorders, color |
1 video switcher |
1 audio mixer |
1 control console |
Cables, tripods, mikes, stands, etc. |
$105,000 |
Table 6

RELATIVE ADVANTAGES OF IMAGE ORTHICON AND VIDICON CAMERA TUBES

<table>
<thead>
<tr>
<th>Item</th>
<th>Image Orthicon</th>
<th>Vidicon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>High: $1,000–2,000 per tube</td>
<td>Moderate: $200–700 per tube</td>
</tr>
<tr>
<td></td>
<td>$15,000–25,000 per camera (b &amp; w)</td>
<td>$500–10,000 per camera (b &amp; w)</td>
</tr>
<tr>
<td></td>
<td>Up to $75,000 for professional quality color camera</td>
<td>Up to $20,000 for professional quality color camera</td>
</tr>
<tr>
<td>Tube life</td>
<td>About 1500 hours</td>
<td>About 5000 hours</td>
</tr>
<tr>
<td>Required light levels</td>
<td>Good for low to moderate light levels; can be damaged at high levels</td>
<td>Good only at high light levels; will &quot;smear&quot; otherwise</td>
</tr>
<tr>
<td>Operating convenience</td>
<td>Requires more experience to operate (e.g., prolonged focus on stationary image may &quot;burn&quot; tube)</td>
<td>Easier to operate; more rugged</td>
</tr>
<tr>
<td>Major applications</td>
<td>1. Highest quality image production</td>
<td>1. General purpose use, especially for low-budget production</td>
</tr>
<tr>
<td></td>
<td>2. Low-light-level use</td>
<td>2. Use in film chains where light level is high</td>
</tr>
</tbody>
</table>

Color capability costs several times as much as black-and-white for both Orthicon and Vidicon tubes. Many of the camera components must be triplicated for the three primary colors, resulting in a much more complex and expensive unit. A color camera incorporates a precision optical system that splits the lens image into three parallel primary color beams (red, blue, and green). Three separate pickup tubes are used, each designed for peak efficiency over its own primary color spectrum, and each with its own scanning circuitry. This redundancy, together with the necessity to maintain the correct balance and proportion of the three color signals, is the reason for the great difference in camera cost.

Video tape recorders (VTRs) are becoming increasingly important for cablecasting, since they provide the only practical method to date of storing and playing back video information without conversion to and from another medium. Film, for example, requires optical-to-electronic conversion. The VTR was introduced to the TV broadcasting industry in 1956. Since then, equipment in a wide range of sizes, capabilities, and prices has become available.

The professional standard for broadcasting is the "quadruplex" recorder, using 2-inch-wide tape. (The term "quadruplex" derives from the four magnetic heads used.) Quadruplex recorders are expensive, from $20,000 each for monochrome to more than $100,000 for a high-quality color unit. They also are large and bulky, not suitable for mobile or portable use.

More recently, a second technique called "helical-scan" or "slant-track" recording has been developed, permitting manufacture of smaller, lower-cost VTRs. Helical-scan recorders now come in a variety of tape widths (from 1/2 inch to 2 inches), tape speeds, and performance characteristics. They range in cost from below $1000.
for 1/2-inch monochrome units to about $15,000 for 1-inch color recorders. The 1/2-inch units have become particularly popular for outside-the-studio recording since they are portable as well as cheap. Figure 9 illustrates this equipment in use in a series of video workshops for the deaf held recently in Reading and York, Pennsylvania by the Community Video Workshop of Berks-Suburban TV Cable Company.

A major problem with helical-scan recorders has been their lack of standardization. Until recently, tapes recorded on one manufacturer's model could not be played back on another manufacturer's unit. Sometimes different recorders even of the same make and model were incompatible. The result has been to inflict severe limits on program interchange. In New York City, many 1/2-inch tapes prepared by individuals and groups for use on the public access channels must be converted to a different format before they can be played.

Within the past two years, Japanese VTR manufacturers have established standards for 1/2-inch and 3/4-inch equipment that should greatly reduce the compatibility problem. Consequently, cable systems and public-access groups can plan to exchange videotapes with some confidence that they will be playable on other systems.

New cassette and cartridge VTRs promise to expand the use of videotape even further. The 3/4-inch equipment pioneered by Sony and Panasonic produces color pictures of much better quality than the black-and-white tapes made on 1/2-inch machines. And the elimination of reel-to-reel threading makes cassette VTRs easier to use by unskilled operators. From the cable system operator's point of view, cassettes permit greater automation in cablecasting. Presently made cassette equipment is heavier and less portable than 1/2-inch VTRs, however.

**MOBILE FACILITIES**

As in broadcasting, many events that are of interest for cablecasting do not take place in the studio. The ubiquitous city council meetings and local high school basketball games, so often mentioned as examples of the benefits of cablecasting, are but two cases in point.

The mobile equipment package for covering remote events does not differ in principle from studio equipment. At a minimum, it comprises a video camera, VTR, and a control unit, plus the associated tripod, microphones, and cabling. The control unit contains a video monitor and controls to compensate for local lighting conditions. Power is usually obtained from the vehicle battery or from portable battery packs. Several manufacturers offer mobile packages, from small units that can fit into the back of a passenger car to custom mobile truck installations. The prices vary accordingly, from about $5000 to $30,000 for black-and-white, and proportionately higher for color.

In most cases, the program is recorded on videotape, which is then transported physically to the cablecasting studio for later playback. If real-time cablecasting is desired, a communication link to the studio is necessary. Special short-range, portable microwave links are available for this purpose.
Fig. 9—Using a portable, half-inch videotape recorder and camera
PROGRAM PRODUCTION

The costs of cablecasting hardware (e.g., cameras and VTRs) and technical operating personnel (e.g., cameramen and console operators) can be estimated fairly accurately. Program production and other software costs are more difficult to forecast.

The simplest kind of cablecasting, such as a one-camera recording of a local meeting without editing, may cost as little as $50 to $100 an hour. An hour of blank, 1/2-inch videotape itself costs $20 to $30. Taping a classroom lecture with some editing may run $500 to $1000, although colleges today typically budget $2000 to $3000 per final program hour.²

On the other hand, cablecasting an original drama, involving script, cast, costumes, sets, lighting, and rehearsals can easily run into tens or hundreds of thousands of dollars. A cost of $1000 to $2000 per viewing minute is considered a realistic guide for the production of commercial filmed or taped programs with no "star" actors.

Past cablecasting has naturally clustered at the low end of the scale in cost and production quality. Still, local programming has improved steadily from the days of presenting a clock face or weather dial to subscribers. Certainly, the technology is available to support cablecasting as a unique medium in its own right, not as simply a lower-cost, lower-quality imitation of broadcast television.

IV. INTERCONNECTION OF CABLE SYSTEMS

FORMS OF SYSTEM INTERCONNECTION

In the past, cable systems have served their own communities alone. With very few exceptions, they have not been linked together to exchange programming. However, several forms of interconnection will be important for new cable systems built in the major markets.

Internal Interconnection (Subdistricting)

Neighborhoods or communities within a franchise area may want different programming, owing to ethnic, cultural, or economic interests. Providing certain channels to some areas and not others is called internal interconnection or "subdistricting." For example, New York City requires Manhattan franchises to divide their cable systems into at least 10 subdistricts. Subdistricts presumably would be selected to conform to traditional, identifiable communities, or to political district boundaries.

Area Interconnection

Cities that franchise more than one cable operator often will require that certain programs be shown simultaneously on all systems. Moreover, most large cities will need more than one headend, since present amplifier technology limits the area that can be served from a single point. Consequently, distributing programming simultaneously throughout the city will require interconnection of the multiple headends or hubs, as shown in Fig. 10. Hub interconnection may be particularly important for distributing public access and other community programming to geographically separated neighborhoods that share similar interests. For example, access programming produced in Harlem may be of far more interest to citizens in Bedford Stuyvesant—across the East River and in a different Borough—than to adjacent neighborhoods on Manhattan’s upper east side.

Area interconnection may also extend beyond a single jurisdiction, especially to include a city and its surrounding suburbs. Here there are several factors to be considered. Metropolitan-wide interconnection may be important in strengthening common bonds between city residents and suburbanites, rather than creating elec-
tronic barriers between them. New services, moreover, such as televised university extension classes and sports events on pay TV, may not be feasible unless distributed simultaneously to a large base of subscribers in a number of cable systems. Finally, suburban cable systems in the major markets may not prosper unless they are interconnected with other suburbs or the central city. However, metropolitan-wide interconnection also raises issues of possible cross-subsidy and equitable sharing of interconnection costs. These points are discussed in recent studies of metropolitan cable systems.¹

Networking

Networking implies interconnection of cable systems that are not physically adjacent, primarily to receive the same programming simultaneously. It offers a strong economic incentive for program producers and advertisers by increasing the audience above that reached by a single system. Networking is exactly the opposite of community-oriented programming, of course, both in philosophy and in the interconnection technology involved. Nevertheless, a cable system may have to provide both kinds of capability.

Cable systems are now thinking of networking on a regional or national basis, probably by satellite. Several companies have proposed to distribute programming

to cable systems when the first U.S. domestic satellite systems become operational after 1975. National networking on a trial basis using the Canadian satellite system may begin this year.

INTERCONNECTION TECHNIQUES

Internal interconnection requires a separate trunk line for each subdistrict and switching equipment at the headend. Switching costs are minor if only one or two channels are involved—for example, switching a single public access channel at the headend to carry programs originated in one of the subdistricts. It will cost much more to enable each subdistrict to receive access programs simultaneously from all the other subdistricts.

Headend or hub interconnection will be by cable or microwave relay. The basic problem is to degrade signals as little as possible between headends, but some loss of signal quality is inevitable. Consequently, system designers must take interconnection losses into account in laying out the distribution system around each hub. In the worst case, signals travel from the far end of one system to its headend, then via the interconnection path to another headend, and finally downstream to the far end of the second system. The signals will go through twice as many amplifiers and hence suffer twice as much degradation as signals that are received off-the-air at a headend.

Cable interconnection uses a large-diameter coaxial cable, often called "supertrunk," to reduce losses. Interconnected signals may also be translated to lower frequencies where attenuation is less. The larger the cable and the fewer the channels carried, the greater the distances between headends that can be connected with supertrunk. Supertrunk connecting hubs five to ten miles apart may be able to carry 20 channels or more, if each hub distribution system has been well designed. Supertrunk runs can be 15 miles or longer if only a few channels are carried. A separate cable must be installed between each pair of interconnected points, of course, and the total cost is proportional to the total number of cable miles required. Two cables may be needed for each link if signals are to be transmitted in both directions.

Microwave relay often has signal-quality and cost advantages over supertrunk when many points must be interconnected, or when hubs are more than 10 miles apart. All microwave links must be licensed by the FCC. The FCC has allocated a 250 MHz bandwidth in the microwave region for "Cable Television Relay Service," or "CARS" (an acronym from its former designation, Community Antenna Relay Service). Single-channel CARS band transmitters and receivers originally were developed to relay distant signals in a series of "hops" of 25 to 30 miles. No more than 10 television channels can be carried from one point to another with this equipment.

Since urban cable systems may need interconnection of more than 10 channels, manufacturers recently have developed equipment to transmit up to 18 channels from a central point to outlying hubs. Microwave links of this sort are known as Local Distribution Service (LDS). The central LDS transmitter is more expensive than a single-channel CARS band transmitter, but the overall system cost may be much lower if many interconnection channels are required. Consequently, LDS
Table 7
COMPARISON OF CABLE AND MICROWAVE INTERCONNECTION FEATURES

<table>
<thead>
<tr>
<th>Feature</th>
<th>Cable</th>
<th>Microwave (CARS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20-30 channels per cable</td>
<td>2 groups, each with 18 operational and 1 calibration channel; normally only one group is assigned in each area</td>
</tr>
<tr>
<td>Channel capacity</td>
<td>Limited to 10 channels by FCC restrictions</td>
<td></td>
</tr>
<tr>
<td>Capital cost</td>
<td>About $5000-7000 per mile (serial installation)</td>
<td>About $100,000 for an 18-channel transmitter; $5000-6000 for each receiver</td>
</tr>
<tr>
<td>Reliability</td>
<td>Excellent (assuming maximum trunk cable distances not exceeded)</td>
<td>Subject to some atmospheric disturbance; long-term reliability not established due to newness of equipment</td>
</tr>
<tr>
<td>Maximum transmission distance for good quality signals</td>
<td>5-15 miles, depending on cable diameter and bandwidth to be carried</td>
<td>20-35 miles</td>
</tr>
<tr>
<td>Two-way capability?</td>
<td>Yes, but generally requires two cables per link at about a 50-percent increase in cost per mile</td>
<td>Yes, at a cost increase of about $5000-10,000 per reverse channel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not with present systems</td>
</tr>
</tbody>
</table>

promises to be a popular technique for high-capacity areawide interconnection. However, present LDS systems are one-way only; returning signals from outlying hubs to the central point, or transmitting signals among headends, would require separate cable or microwave links.

The choice of technique thus involves the number of interconnected headends, the number of channels carried, distances, and whether one-way or two-way transmission is required. Table 7 gives a brief comparison between cable and microwave interconnection. Some systems may use a combination of the two—for example, LDS for multichannel transmission from a master headend to outlying hubs, with cable connections back to the master headend for return communications. The best area interconnection technique must be worked out in each individual case.
V. TWO-WAY COMMUNICATIONS

Besides transmitting "downstream" to the home, a coaxial cable can carry information back "upstream" from subscribers. This ability suggests a great variety of new services and gives cable television much of its "blue-sky" allure.¹

The FCC now requires each new major-market cable system to "maintain a plant having technical capacity for nonvoice return communications." This is interpreted to mean that the system meets the FCC's intent if it eventually can provide return communication (from subscribers to the headend) without "time-consuming and costly system rebuilding."²

A listing of proposed two-way or interactive services, adapted from a previous Rand report, appears as Table 8. These can be categorized broadly into two groups: services for individual subscribers, and services for institutions.

SUBSCRIBER SERVICES

Television pictures, voice conversations, and data messages are all carried on the cable as electrical signals; they differ primarily in the frequency bandwidth and the subscriber equipment each requires. In principle, a subscriber could send data, voice, or video signals upstream to the headend or to other subscribers on a two-way cable system. In practice, bandwidth constraints and terminal costs will make televi-


² Sec. 129 of the FCC Cable Television Report and Order, 37 Fed. Reg. 3252, 1972 reads as follows:

We are not now requiring cable systems to install necessary return communication devices at each subscriber terminal. Such a requirement is premature in this early stage of cable's evolution. It will be sufficient for now that each cable system be constructed with the potential of eventually providing return communication without having to engage in time-consuming and costly system rebuilding. This requirement will be met if a new system is constructed either with the necessary auxiliary equipment (amplifiers and passive devices) or with equipment that could easily be altered to provide return service. When offered, activation of the return service must always be at the subscriber's option.

35
Table 8

SOME PROPOSED INTERACTIVE SERVICES FOR CABLE TELEVISION

<table>
<thead>
<tr>
<th>Subscriber</th>
<th>Institutional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive instructional programs</td>
<td>Computer data exchange</td>
</tr>
<tr>
<td>Fire and burglar alarm monitoring</td>
<td>Teleconferencing</td>
</tr>
<tr>
<td>Television ratings</td>
<td>Surveillance of public areas</td>
</tr>
<tr>
<td>Utility meter readings</td>
<td>Fire detection</td>
</tr>
<tr>
<td>Control of utility services</td>
<td>Pollution monitoring</td>
</tr>
<tr>
<td>Opinion polling</td>
<td>Traffic control</td>
</tr>
<tr>
<td>Market research surveys</td>
<td>Fingerprint and photograph identification</td>
</tr>
<tr>
<td>Interactive TV games</td>
<td>Civil defense communications</td>
</tr>
<tr>
<td>Quiz shows</td>
<td>Area transmitters/receivers for mobile radio</td>
</tr>
<tr>
<td>Pay TV</td>
<td>Classroom instructional TV</td>
</tr>
<tr>
<td>Special interest group conversations</td>
<td>Education extension classes</td>
</tr>
<tr>
<td>Electronic mail delivery</td>
<td>Televising municipal meetings and hearings</td>
</tr>
<tr>
<td>Electronic delivery of newspapers and periodicals</td>
<td>Direct response on local issues</td>
</tr>
<tr>
<td>Remote calculating and computer time sharing</td>
<td>Automatic vehicle identification</td>
</tr>
<tr>
<td>Catalog displays</td>
<td>Community relations programming</td>
</tr>
<tr>
<td>Stock market quotations</td>
<td>Information retrieval services</td>
</tr>
<tr>
<td>Transportation schedules</td>
<td>Education for the handicapped</td>
</tr>
<tr>
<td>Reservation services, ticket sales</td>
<td>Drug and alcohol abuse programs</td>
</tr>
<tr>
<td>Banking services</td>
<td>Health care, safety, and other public information programs</td>
</tr>
<tr>
<td>Inquiries from various directories</td>
<td>Business transactions</td>
</tr>
<tr>
<td>Local auction sales and swap shops</td>
<td>Credit checks</td>
</tr>
<tr>
<td>Electronic voting</td>
<td>Signature and photo identification</td>
</tr>
<tr>
<td>Subscriber originated programming</td>
<td>Facsimile services</td>
</tr>
<tr>
<td>Interactive vocational counseling</td>
<td>Industrial security</td>
</tr>
<tr>
<td>Local ombudsman</td>
<td>Production monitoring</td>
</tr>
<tr>
<td>Employment, health care, housing, welfare, and other social service information</td>
<td>Industrial training</td>
</tr>
<tr>
<td>Library reference and other information retrieval services</td>
<td>Corporate news ticker</td>
</tr>
<tr>
<td>Dial-up video and audio libraries</td>
<td>Telediagnosis</td>
</tr>
<tr>
<td>Videophone</td>
<td>Medical record exchange</td>
</tr>
</tbody>
</table>

*It is unlikely that all of these services will be economically feasible on cable television networks. Some may not even be socially desirable. They have been compiled from various reports, FCC filings, corporate brochures, and advertising materials. Adapted from Baer, *Interactive Television.*
sion origination from the home too expensive for all but specialized applications.\(^3\) Eventual video links among subscribers are much more likely to come about on the switched telephone network than on a party-line cable system. The telephone also will remain a better choice for private conversations.\(^4\)

Consequently, an upstream return path from the home will be used principally to carry data messages from subscribers. These messages could include responses to questions asked on an educational program, opinions on a proposed city ordinance, and orders to buy the sewing machine just advertised on the screen. Fire and burglar alarm messages also could be sent automatically to a central station.

These messages all have common characteristics. They require much less bandwidth than voice conversations, and they can be encoded in digital form for rapid computer processing. Moreover, digital messages from thousands of subscribers can be packed together into a single data stream that uses the upstream cable capacity very efficiently.

Each subscriber would have his own digital code or “address” for two-way response services. A computer at the headend (or some other suitable location) would query each subscriber in turn, using a special downstream channel. This technique is known as “polling.” A two-way terminal attached to the cable and TV set would record the subscriber’s messages, store them, and send them upstream when the terminal was polled. The messages would then be recorded at the headend computer or sent on to the city council chambers, the police station, or the department store.

The basic subscriber response terminal looks like a small box with a telephone-like keyboard and a lock to prevent unauthorized use (Fig. 11). A tunable converter might be built in, and smoke sensors, burglar alarms, and utility meters could be connected to it. Several companies are now experimenting with prototype subscriber terminals. They cost close to $1000 today, but industry sources estimate that further development and mass production may reduce the price to $100 or so by 1980.

Some specific two-way services such a terminal can handle include:

- Counting the number of subscribers tuned to a given channel
- Ordering an air conditioner advertised on “special sale”
- Requesting a pay-TV movie
- Answering a multiple choice quiz presented as part of a televised college class
- Responding to a political opinion poll
- Reading utility meters automatically
- Monitoring fire and burglar alarms

Other services, such as browsing through a catalog displayed on the TV screen, making theater reservations, or requesting a paragraph from the *Encyclopaedia Britannica* will require more complex subscriber terminal equipment.

---

\(^3\) For example, two-way video links between a classroom and handicapped children at home were demonstrated on the cable system in Overland Park, Kansas. Continuing service was not economically feasible, however, and the demonstration was terminated after a few months.

\(^4\) Cable systems might install a shared upstream voice channel, although cable’s advantage over the telephone seems questionable. For example, a city council meeting televised on a two-way cable system might allocate time for audience questions and comments. With the proper equipment at home and in the city council chambers, a subscriber could signal to be heard and then wait his turn until an upstream voice channel were available. While his question was being transmitted upstream, that voice channel would be denied to other users.
Fig. 11—Typical terminals for two-way subscriber response services
INSTITUTIONAL SERVICES

Institutional users of the cable system may want and be able to afford more expensive terminals and greater upstream capacity. These users include:

- Businesses that want high-speed computer data exchange
- Industrial plants that televise extension courses with student feedback to a nearby university
- Schools that want two-way video for in-class instruction and after-school teacher meetings
- Hospitals that exchange medical records and diagnostic test results, and hold two-way video consultations
- Police agencies that transmit fingerprints and photos among precinct houses, or monitor streets and public areas with remote TV cameras
- Local government agencies that want two-way video links for teleconferencing

Experiments in each of these uses are under way today, although they generally use microwave links, closed-circuit systems, or the telephone network rather than cable.\(^5\)

TWO-WAY TRANSMISSION TECHNIQUES

Two-way services by definition require a cable system that can transmit information in both directions. The chief technical difficulty today is that each TV set or subscriber terminal introduces some noise into the upstream transmission path, and the cumulative effect from large numbers of terminals may be intolerable. Better receivers, taps, filters, and other components must be designed before two-way cable systems can accommodate the tens of thousands of subscribers contemplated in major markets.

The two basic technical approaches to two-way transmission are:

1. Use separate cables for upstream and downstream transmission;
2. Send signals in both directions simultaneously on the same cable, using different frequency bands to separate the upstream and downstream signals.

A third approach would use a one-way round-robin cable loop to bring signals to and from subscriber locations. While interesting conceptually, this technique has not yet been applied on operating cable systems. The three approaches are shown schematically in Fig. 12.

Having a separate cable for upstream transmission presents fewer technical problems and offers more upstream capacity, but is more expensive. An ordinary telephone wire or wire pair used for the upstream path would satisfy the FCC's

Subscribers

(a) Two-way transmission on a single cable

Subscribers

(b) Separate cables for upstream and downstream transmission

Subscribers

(c) Round-robin cable loop

Fig. 12—Three techniques for two-way transmission
requirement for "nonvoice return communications," but would provide little capacity for future services.

Carrying signals in both directions simultaneously on a single cable costs less than installing separate cables but is more complex. Upstream and downstream signals must be separated in frequency to avoid interference. The most popular approach today is to use the sub-VHF bandwidth below channel 2 (below 54 MHz) for upstream signals, retaining the 54 to 300 MHz bandwidth for downstream transmission. This is known as the "subsplit" or "low-split" technique.

The coaxial cable itself is bidirectional and poses no problems to two-way transmission. Amplifiers, however, are one-way devices and require some by-pass path for signals going in the opposite direction. Consequently, the upstream and downstream signals must be routed to different amplifiers and must be separated by electronic filters, as shown in Fig. 13. In practice, filters do not separate frequencies as sharply as might be desired. To allow enough of a "guard-band" to prevent interference, most system designers restrict upstream signals to no higher than 30 MHz, rather than 54 MHz. A similar precaution is taken not to use frequencies below about 5 MHz, since the electronic filters used in amplifier power supply circuits cut off these low frequencies. As a result, the subsplit approach limits upstream transmission to about 5 to 30 MHz, a 25 MHz bandwidth equivalent to four standard TV channels.

The single-cable approach is popular with cable operators because its installation cost is lower. Moreover, if the system has no immediate plans to use upstream communications, only the downstream amplifiers need be installed initially. Purchase and installation of the filters and upstream amplifiers shown in Fig. 13 can be deferred to a later date. Amplifier manufacturers offer models with housings large enough to accommodate plug-in modules for activating upstream communications in the future. At present, this satisfies the FCC requirement for "technical capacity for nonvoice return communications."

Fig. 13—Simultaneous two-way communication on a single cable
Although economically attractive, the subsplit technique suffers first from its limitation in upstream bandwidth. Although 25 MHz may be sufficient for subscriber response data services, heavy institutional demand for two-way video channels will require additional upstream capacity. As a result, a "midsplit" technique has been devised that divides upstream and downstream signals between 108 and 160 MHz, permitting 14 or more 6 MHz channels in each direction. The subsplit and midsplit techniques are compared in Fig. 14.

Of course, a single cable system built in a major market could not adopt the midsplit technique, since it then could not deliver 20 downstream channels as the FCC rules require. A midsplit system thus implies two or more cables—the first carrying 20 or more channels downstream, and the second with the capability for 14 or more channels in both directions. This second cable can exist in "shadow" form, however, as described in Sec. II, with only the cable and housings for electronics installed initially, and the electronic components added later. The single operating cable plus shadow-trunk design is currently very popular with operators, since it entails (initially) only the extra cost of the second cable and provides both one-way and two-way expansion capacity for the future.

Still, the technical problems have not been fully resolved, particularly for the subsplit approach. Designing filters for two-way operations is difficult; each filter will add some distortion to the downstream video signal, and the cumulative effect of many amplifiers in cascade may be an unacceptable picture. Although the problem should be worked out in time through experience and better filter design, it has been a barrier to early two-way development. At the very least, the need for two-way filters will restrict the number of amplifiers that can be cascaded, and thus further limit the area that can be served from a given headend.

In summary, a simplified cost comparison of several two-way system designs is shown in Table 9. These estimates should be compared with the costs of one-way systems listed in Table 4.

The separate-cable approach to two-way cable communications is presently more reliable, but more costly. The single-cable approach minimizes initial cost, but is technically more risky. Neither approach solves the problem of additive upstream noise from subscriber terminals. Once again, the benefits from added two-way capacity are more difficult to quantify than the costs, and there is no "best answer" for every community. Some cities may want to require dual trunk and feeder cables—at least in shadow form—that can be used to expand either upstream or downstream capacity, or some combination of both. A city that foresees a need for extensive two-way capacity among schools, hospitals, and other institutional users may prefer to install entirely separate cables for these applications.

**TWO-WAY DEMONSTRATION PROJECTS**

The first field tests of two-way cable communications began in 1971. (Table 10 lists the major ones.) They are being conducted today only as tests of equipment for subscriber response services, not as attempts to deliver two-way services to paying subscribers. As of May 1, 1973, fewer than 100 two-way subscriber terminals were in active operation in the United States. Additional tests are planned in the United
(a) Using "sub-split" filters

(b) Using "mid-split" filters

Fig. 14—Subsplit and midsplit techniques
Table 9  
COST COMPARISON OF TWO-WAY CABLE SYSTEM DESIGN OPTIONS

<table>
<thead>
<tr>
<th>System Characteristics</th>
<th>Cost per Mile, Aerial Cable Distribution Plant</th>
<th>System Cost per Subscriber, a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single cable with converters, 20-30 channels downstream, plus wire pair for upstream transmission</td>
<td>$5800-6800</td>
<td>$195-220</td>
</tr>
<tr>
<td>Single cable with converters, 20-30 channels downstream, plus shadow trunk for eventual two-way transmission</td>
<td>$6500-7500</td>
<td>$210-240</td>
</tr>
<tr>
<td>Single cable with converters, subsplit, 20-30 channels downstream, 4 channels upstream</td>
<td>$6500-8000</td>
<td>$210-250</td>
</tr>
<tr>
<td>Dual cable, each cable with subsplit, 12 channels downstream, 4 channels upstream</td>
<td>$8800-9500</td>
<td>$260-255</td>
</tr>
<tr>
<td>Dual cable with converters: first cable, 20-30 channels downstream; second cable mid-split, 14 channels downstream, 16 channels upstream</td>
<td>$9500-11,000</td>
<td>$290-330</td>
</tr>
<tr>
<td>Dual cable with converters: first cable, 20-30 channels downstream; second cable, 20-30 channels upstream</td>
<td>$7800-9800</td>
<td>$245-295</td>
</tr>
</tbody>
</table>

a Assumes 100 homes per mile, converters at $35, dual cable switches at $4, headend costs of $15 per subscriber.
b Minus channels unusable due to on-channel interference.

States and Canada later this year in which subscribers will be charged for two-way services they receive.

These demonstrations all follow the same general approach and use equipment with the same functional characteristics; that is:

- They are subscriber rather than institution oriented.
- They use digital data communications exclusively. A message from a subscriber may trigger a nondigital action, such as switching a pay-TV program into his home, but that is ancillary to the actual two-way communications.
- Communications in both directions are computer-controlled.
- They use the single-cable, subsplit technique for two-way transmission, as shown in Table 10.
- They poll subscribers in sequence to see if a message is waiting, provide an appropriate response, and then proceed to the next subscriber. Table 10 shows the maximum polling rate designed for each system.

To no one’s surprise, a number of the technical problems described above have shown up in these tests. Additive upstream noise has been a particularly vexing
<table>
<thead>
<tr>
<th>Equipment Manufacturer</th>
<th>Test Location</th>
<th>Transmission Frequency Band (Mhz)</th>
<th>Subscriber Polling Rate per Second (Design Limit)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theta-Com</td>
<td>El Segundo, Calif.</td>
<td>108-112</td>
<td>21-25</td>
<td>5000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Downstream</td>
<td>Upstream</td>
<td>20-25 terminals installed in first phase; plans for 1000 terminals within one year</td>
</tr>
<tr>
<td>Electronic Industrial</td>
<td>Orlando, Fla.</td>
<td>88-108</td>
<td>12-14</td>
<td>1000</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td>Downstream</td>
<td>Upstream</td>
<td>24-27 terminals installed in first phase; plans for 500 terminals in 1973</td>
</tr>
<tr>
<td>Scientific-Atlanta</td>
<td>Carpenterville, Ill.</td>
<td>111.1-113.9</td>
<td>0.225-0.275 or 5.25-5.75</td>
<td>820</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Downstream</td>
<td>Upstream</td>
<td>6 terminals installed for fire and burglar alarms; plans for operations later in 1973</td>
</tr>
<tr>
<td>TOCOM</td>
<td>Irving, Tex.</td>
<td>50</td>
<td>6-30</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Downstream</td>
<td>Upstream</td>
<td>Planned for installation later in 1973</td>
</tr>
</tbody>
</table>
problem. Still, the technology for two-way subscriber response services is known, and the engineering problems will be resolved in time. By 1980 most large U.S. cable systems should have operating two-way transmission facilities. The prospects for using these facilities for two-way subscriber or institutional services are less clear, however, and await the first full-scale market tests sometime later in this decade.  

6 The Federal Government may also play a role in initiating two-way demonstration projects. In 1972, the President's Office of Telecommunications Policy released a major study and requested statements of qualifications from organizations that might plan demonstration projects using telecommunications technology. See Pilot Projects for the Broadband Communications Distribution System, Malarkey, Taylor & Associates, Washington, D.C., November 1971; and Commerce Business Daily, August 25, 1972, p. 12, for details. However, no federal support for such projects has yet been announced.
VI. TECHNOLOGY FOR NEW SERVICES

PAY TV AND PRIVATE CHANNELS

Pay television (or pay-cable, as the FCC now terms it) will be the first new service offered by most cable systems. Viewers will pay an extra charge (over and above the basic cable subscription fee) to watch first-run movies, sports events, theater productions, and other special programs. Pay-TV movies have already proved successful in hotels and motels. Several Pay-TV experiments now are under way on cable systems (Table 11), and cable operators estimate that they will have more than one million pay-TV subscribers by the end of 1974.

Subscribers will watch pay-TV programs on their standard TV sets. New equipment will be needed, however, to deny the programs to those who do not want to pay for them, and to record the proper charges for those who do.

The simplest technical approach is to send pay-TV programs on special frequencies—perhaps in the midband or superband—and furnish pay-TV subscribers with a special converter to receive them. To guard against subscribers tapping in for free, pay-TV promoters usually code or scramble the signals at the headend. A decoder as well as a converter is then required in the subscriber’s pay-TV terminal. Some of the first pay-TV terminals are illustrated in Fig. 15. For further security the operator can install a switch inside the terminal that can be turned on and off only from the headend. He might even take the decoding terminal out of the home entirely and place it at the tap or at a feeder amplifier. Each step is successively more costly, but provides greater protection. The same cost and security considerations would apply to private channels that only certain subscribers are entitled to receive. Private channels might be needed for police training classes, for example, or for assuring privacy for banking transactions in a two-way system.

The simplest form of billing is to charge a fixed amount each month, no matter how much or how little pay-TV programming the subscriber watches. Both pay-TV promoters and viewers prefer, however, that charges be made on a per-program basis. To do this, the subscriber must be able to signal when he wants a particular program and to be billed accordingly.

In one currently demonstrated pay-TV system, subscribers purchase a “ticket”—shaped somewhat like a plastic credit card—in advance to watch particular pay-TV programs. When the program is shown, he places the ticket in a special slot in his pay-TV terminal. The ticket contains magnetic strips or holes that activate decoder circuits to provide an undistorted picture on the screen. Each program is
### Table 11

**PAY-TV EXPERIMENTS ON CABLE TELEVISION SYSTEMS**

<table>
<thead>
<tr>
<th>City</th>
<th>Cable Operator</th>
<th>Pay-TV Operator</th>
<th>Type of System</th>
<th>Beginning Date</th>
<th>Programs Offered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wilkes-Barre, Allentown, other Pa. cities</td>
<td>Service Electric</td>
<td>Home Box Office (partially owned by Time, Inc.)</td>
<td>one-way, with tickets, monthly fee</td>
<td>Nov 1972</td>
<td>Sports, movies</td>
</tr>
<tr>
<td>Sarasota, Fla.</td>
<td>Storer Broadcasting</td>
<td>Theatre Vision</td>
<td>one-way, monthly fee</td>
<td>Jan 1973</td>
<td>Sports, movies, cultural events</td>
</tr>
<tr>
<td>San Diego, Calif.</td>
<td>Cox Cable</td>
<td>Optical Systems</td>
<td>one-way, with tickets, monthly fee</td>
<td>Mar 1973</td>
<td>Sports, movies</td>
</tr>
<tr>
<td>Long Beach, Calif.</td>
<td>Times-Mirror CATV</td>
<td>Cintra Communications</td>
<td>one-way, monthly fee</td>
<td>Mar 1973</td>
<td>Movies</td>
</tr>
</tbody>
</table>

**NOTE:** These pay-TV experiments were actually under way on cable systems as of April 1, 1973. Additional experiments are planned for 1973 or early 1974 by Cablecom-General/Home Theatre Network, Trans-World Communication, TelePrompTer/Magnavox, American Television & Communications/RCA, Theta Cable/Theta-Com, and others.
Fig. 15—Home terminals for pay television
encoded at the headend in a different manner, so that the subscriber must buy separate tickets for movies, hockey games, and other events. As a slight variant, the subscriber can telephone to find out the code for a particular program he wants to watch. His request is recorded for billing, and he is given instructions to punch out certain holes on a previously unused ticket. This allows him to make a last-minute decision to watch a pay-TV program.

Under a different scheme, the subscriber calls in for each pay-TV program he wants to see. No previously purchased tickets are required. Instead, a signal is sent from the headend when the subscriber’s request is received to switch on the decoder circuits in his terminal. This approach requires more expensive terminals and headend equipment, but it permits all pay-TV decisions to be made up to the last moment. Some pay-TV promoters consider that such impulse buying will be essential to their financial success.

These systems can be installed on a one-way cable system. The added hardware costs are estimated at $5000 to $10,000 per channel at the headend, and $40 to $100 for each subscriber terminal. The equipment has not been in service long enough to make reliable estimates of reliability and maintainability, but it is likely that these “first generation” pay-TV terminals will be superseded by others within 2 or 3 years.

At least two pay-TV experiments are planned on two-way cable systems in 1973. In a two-way system, pay-TV requests could be sent upstream on the cable, eliminating the need for tickets or a telephone return link. Two-way pay-TV also has other advantages, but its equipment is considerably more expensive. The very fact that pay-TV can be installed more cheaply as a one-way service may prove a formidable barrier to the early installation of two-way home terminals.

INFORMATION RETRIEVAL AND FRAME STORAGE

The subscriber response services described in Sec. V will be the first two-way services developed for the home. A far richer range of services will be possible when the subscriber can request information to be shown on his TV set at his convenience. A few of the many potential examples include:

- Getting help in filling out an income tax form
- Buying theater tickets for Saturday night
- Balancing one’s checking account
- Seeing a map of alternate bus routes
- Finding the last sale price of a specific stock
- Taking a computer-aided Spanish lesson

In the past, some of these services have been available over the telephone. Cable now provides a new way to transmit information and have it displayed on the TV screen.

Information retrieval services will be considerably more complex and costly than subscriber response services. They require much more sophisticated computer and information storage facilities at the headend, and an even greater investment in computer programming or “software.” They also demand a more sophisticated
subscriber terminal that can display requested information as a still picture on the TV screen. The problem is somewhat like that of projecting different frames of a movie film on different screens, one frame at a time, for different viewers. One subscriber might want to see current football scores; another, airline schedules; a third, children’s clothes in a merchandise catalog; and so forth.

Like movies, television presents a series of still pictures ("frames") on the screen rapidly enough that the eye perceives small changes as motion. The U.S. television standard is 60 frames a second. The technology exists for sending these separate frames to different subscribers, with each frame captured at a subscriber’s terminal and replayed over and over for viewing on his TV set. Such terminals are generally known as "frame grabbers" or "frame stoppers." Prototype frame stoppers have been developed using videotape recorders or special "storage tubes" to capture and replay single frames. In the approach recently demonstrated in Reston, Virginia, up to 600 subscribers could in principle be served simultaneously over a single 6 MHz television channel, if new frames were requested every 10 seconds on the average. This demonstration used a telephone line for the return link from subscriber to headend, but the Reston cable system is now being retrofitted for two-way transmission.1

As might be expected, frame-stopping terminals would be very expensive today, even if two-way cable systems were operational. Although development is proceeding rapidly, frame-stopping terminals are still likely to cost considerably more than a color television set in 1980. Consequently, information retrieval services on cable will be available to business, government, and institutional subscribers well before they are feasible in the home.

ELECTRONIC MAIL AND FACSIMILE

Another class of proposed cable services would deliver letters, newspapers, periodicals, and other documents to the home electronically rather than through the mails. Cable's huge capacity makes it potentially more attractive than the telephone network for large-scale, electronic document delivery.2 Using digital addresses, a personal letter could be sent to only one subscriber, while advertising flyers were distributed to an entire neighborhood.

Subscriber terminals are again the pacing technical problem. A frame-stopping device could display documents on the television screen a few paragraphs at a time, if the subscriber did not want to keep a printed copy. However, proponents of electronic mail delivery generally assume that some sort of facsimile or "hard copy" device would be needed in the home. It would scan a downstream channel for addressed digital data, separate the information from the high-frequency carrier, and record text and illustrations on a roll of paper. Developing such devices poses


problems of paper storage and electric power cost, as well as that of building a cheap, reliable home unit. Facsimile devices coupled to cable should be available for institutional use by 1980, but they are even less likely to be used in the home by then than are frame-stopping terminals.

**VIDEOCASSETTE RECORDERS AND CABLE TELEVISION**

A videocassette recorder can record television programs for playback at a later time. As described in Sec. IV, many cable systems will use videocassette equipment to record and play programs from the headend. The elimination of tape threading and open reels greatly simplifies equipment handling.

Videocassette (or video cartridge) recorders now are also being marketed for home use. They can, of course, record broadcast as well as cable television programs, so that they have no direct connection with new cable services. Still, the combination of cable channel capacity and videocassette storage suggests some interesting possibilities. As examples, adult extension courses or pay-TV programs may be offered on cable at inconvenient times for some viewers. An interested subscriber could connect his videocassette recorder to record these programs when transmitted, and then play them back on his TV set at his convenience. Consequently, the availability of cassette recorders should increase the markets for specialized cable programs and perhaps make some marginal ones economically attractive. Cassette recorders may also be used as frame-stoppers or for electronic document delivery, as described above.

Today, videocassette recorders cost upwards of $1000 and are unstandardized. No clear winner has yet emerged from the competing technologies using videotape, film, or recording discs. Costs are sure to come down in the future, however, so that these devices may become standard household items in the 1980s. Some cable system operators may in fact rent cassette units to subscribers to enhance the market for their services.

**HIGH-RESOLUTION TV**

Cable systems eventually will deliver bigger, brighter, and sharper television pictures than are standard today. Although cable service is usually purchased to improve reception, television picture quality is limited intrinsically by the channel bandwidth and by the poor reception characteristics of most TV sets. Some observers believe that viewers will demand higher quality sound and pictures before they will pay a separate charge for movies, operas, ballets, and other performances.

If demand warranted, these events could be transmitted over a 10 or 12 MHz channel and displayed on special "high-resolution" TV receivers. High-fidelity, stereo sound could accompany the higher-quality pictures. A well-designed cable system could carry these channels without affecting transmission of the standard 6
MHz channels, whereas it would be very difficult to reallocate the broadcast spectrum to accommodate high-resolution television.\textsuperscript{3}

High-resolution TV sets for the home remain to be developed. The scientific principles are well known, but difficult technical and cost barriers remain in the way of producing high-resolution receivers for consumers. Moreover, standards for high-resolution TV would have to be adopted by program producers, cable distributors, and receiver manufacturers before the service could be provided. For these reasons, high-resolution TV in the home is not likely to be widely available before 1990, although it may be feasible in theaters and group viewing centers well before then. Video projection systems that offer larger screen size but no higher resolution are also under development.

**INSTITUTIONAL SERVICES**

All the above new services are ultimately targeted at mass subscriber audiences, although they may be feasible for businesses, schools, and government agencies before they reach the home. Some cable applications will be developed expressly for institutional users, however. Among others, these include:

- Teleconferencing and other two-way video uses
- Video surveillance
- High-speed data transmission

**Teleconferencing**

Two-way audio and video links may enable people at scattered locations to hold meetings and discussions. Government agencies, businesses, hospitals, and schools can all use teleconferencing to save time and establish more effective patterns of communication.\textsuperscript{4} A consortium of local governments around New York City, the Metropolitan Regional Council, is now developing teleconferencing links by microwave to improve local agency cooperation and administration.\textsuperscript{5} Two-way video links between a hospital and outpatient clinics provide a more dramatic example. One such prototype system permits specialists at Massachusetts General Hospital to diagnose patients at the emergency medical station at Boston's Logan Airport.\textsuperscript{6} This system again uses a microwave link, but a two-way cable system would offer an attractive alternative if available.

The equipment for teleconferencing is similar to that long used in closed-circuit


\textsuperscript{4} Obviously, teleconferencing cannot substitute for all face-to-face meetings and discussions. The tradeoffs are subtle and, for the most part, unknown. See Richard C. Harkness, *Communications Innovations, Urban Form and Travel Demand*, Research Report No. 71-2, Urban Transportation Program, University of Washington, Seattle, January 1972, for a survey and bibliography of research in this area.


\textsuperscript{6} For further discussion of this and other health services applications, see Yin, *Cable Television: Applications for Municipal Services*, and Ras Kaliba, *Communicable Medicine: Cable Television and Health Services*, report prepared for the Sloan Commission on Cable Communications, September 1971.
television systems. For transmission, a video camera and microphone pick up the desired video and audio signals. Special close-up camera attachments may be needed for medical diagnosis or for viewing a printed page or drawing. The outgoing signals are amplified and modulated (i.e., translated to a frequency band authorized for that service), and then sent out over the cable. A video tape recorder can store programs for later transmission and record incoming signals. The video display generally is on a standard TV receiver or monitor, although some applications may require higher resolution or larger screen size. If standard displays are used, the equipment cost at each teleconferencing station will range from $2000 to $5000 for portable black-and-white components, to $20,000 to $40,000 for full color capability.

Each teleconferencing link requires separate 6 MHz channels for upstream and downstream communication, unless special bandwidth compression schemes are employed. However, several stations can share channels, with only one permitted to transmit at a time. Still, heavy use of two-way video would use up a large share of the cable's capacity or, more likely, require installation of separate cables for teleconferencing.

**Video Surveillance**

Several cities have experimented with monitoring streets and other public areas by remote video cameras connected to a central point. Traffic and crime control are the two commonest applications. These are essentially one-way (upstream) video transmission services, sometimes requiring a narrowband downstream link for remotely positioning and controlling the cameras. Here again, slow scan or time-sharing techniques can conserve channel bandwidth. For example, six cameras at six locations can be set to transmit sequentially, so that each location would be seen one-sixth of the time at the monitoring station.

Such services are not difficult technologically. Whether they are socially desirable and worth the cost in equipment and monitoring personnel must be determined by each city.

**High-Speed Data Transmission**

As Table 10 indicates, a large number of business data services have been proposed for two-way cable systems. Businesses today use the telephone network for most of them. Credit checking, for example, can be done with a telephone call—either by requesting verbal clearance, or by using a credit card reader to interrogate a remote computer. Stock market quotation systems use the telephone network to update stock prices displayed on cathode-ray-terminals at brokers' offices. Computer time-sharing services offer access by telephone lines to stored programs that can compute taxes, solve engineering problems, or retrieve information from a central

---

1 Picturephone, under development by AT&T for use over the switched telephone network, requires only a 1 MHz bandwidth instead of 6 MHz. It gives a lower resolution picture but is perfectly satisfactory for many uses. Cable applications such as document display among libraries, fingerprint exchange among police precinct houses, and X-ray or EKG transmission among hospitals may adopt similar bandwidth compression or "slow-scan" techniques.

2 See Yin, *Cable Television: Applications for Municipal Services*, for further discussion.
file. Hotel, airline, theater-ticket, and car rental reservations likewise are available by calling a central computer databank.

Whether cable TV offers a superior method of supplying such services must be evaluated on a case-by-case basis. Generally, however, cable is unlikely to compete effectively with the existing telephone network where point-to-point communications are involved. Moreover, the telephone network will be better able to serve small business and the general public until cable’s penetration nears that of telephone service (92 percent of U.S. residences in 1972).

Conversely, cable’s cost advantage in business applications emerges when a high volume of information is to be exchanged at high speed among only a few users. For example, bank branches within a city might exchange data and update transactions on a dedicated cable channel. As the “checkless, cashless society” approaches, department stores and other retail outlets could tie in to record purchases as they occur. Large corporate computer users also might find cable an attractive transmission medium, especially if cable systems were interconnected to provide national point-to-point links. This may in fact come about in the 1980s through satellite interconnection of urban cable systems, or through interconnection agreements between cable systems and the new specialized common carriers that intend to compete with the established telephone companies and Western Union.

The use of cable systems for high-speed data transmission, however, depends on their reliability even more than cost. Today, business users complain about the telephone network’s reliability and error rate. Cable networks could be designed for reliable, low-error-rate data transmission, but they presently are not. Consequently, businesses may be slow to use the cable, preferring to wait until some proven record of reliability has been compiled. This inertia, while understandable, may defer the widespread use of cable for business services much longer than proponents have sometimes estimated.

VII. TECHNICAL STANDARDS

The problems of establishing adequate technical standards and monitoring cable system performance for compliance with those standards have plagued almost every city granting a cable franchise. Cable technology generally is unfamiliar to city authorities, and the cable industry itself has not agreed on standards. Consequently, there are few if any guidelines to follow.

Past approaches have varied all the way from vaguely requiring "good quality pictures" with no detailed standards at all, to including a long list of technical specifications (some ambiguous, some unmeasurable, and some contradictory) in the franchise ordinance.

The confusion has been somewhat reduced by the 1972 FCC regulations, which now require certain technical standards in all new major-market systems. The standards are far from comprehensive, however, and pertain to performance characteristics only. Such factors as reliability are not covered, even though they determine in large part whether the system adequately fulfills its function.

FCC TECHNICAL STANDARDS

The FCC rules define four classes of cable TV channels. Class I comprises broadcast TV programs that the cable system receives and distributes to subscribers. Class II comprises cablecast programs that originate within the cable system (excluding those for which special decoding or unscrambling devices are required, as for pay-TV). Class III includes other one-way services such as pay-TV, facsimile transmission, or electronic mail delivery. Class IV applies to "reverse" communications, in which information flows from the subscriber to the headend or central distribution center.

Of these four classes, the FCC has established technical standards only for Class I channels. The reason for not setting standards for Class II, III, and IV channels is to encourage experimentation in developing new cable uses and services. The Class I technical standards are reproduced in the Appendix. Broadly speaking, they are designed to insure that most subscribers receive a picture and sound of approximately the quality received off the air in an average reception area.

1 The complete FCC rules are contained in Rivkin, op. cit.
It is important to realize that statistical rather than absolute concepts are involved. The standards do not guarantee that, if met, all subscribers will get excellent pictures, or even that picture quality will necessarily be the same at all points in the cable system. Localized sources of interference may degrade some subscribers’ pictures even though the cable system meets FCC standards.

The minimum performance level also is set below that which many city viewers now receive off-the-air. As a result, most major market cable systems will have to exceed the FCC standards if they are to sell subscriptions in good reception areas. A local franchise can require more stringent technical standards if the local authority is prepared to enforce them itself.²

The complete lack of standards for Class II, III, and IV channels poses some problems for communities. Class II channels are already in use for local origination and public access. The public access channel is a particular source of technical difficulty, since many individuals or organizations using that channel prepare their own programs with inexpensive video cameras and tape recorders. Often such programs taped in the field fall below the quality level the cable operator or subscribers find acceptable. This factor alone can reduce subscriber interest in watching the public access channel.

Moreover, local program interconnection among cable systems may not be possible without technical standards. The FCC-mandated educational and local government channels, for example, fall into Class II. There is presently no assurance that a taped program prepared by a school district or government agency for distribution over one cable system would be compatible with the cablecasting equipment of a second cable system—even within the same city. Requiring such technical compatibility is now left to local authorities.

Some Class III and IV channels are also coming into use, but are not yet at the point where meaningful technical standards can be established. Pay-TV (Sec. VI) falls into Class II, while experiments with two-way communications (Sec. V) fall under Class IV.

WRITING AND ENFORCING LOCAL TECHNICAL STANDARDS

As an electrical system, cable TV must meet applicable state, county, and city building codes that specify construction standards, materials, grounding and shielding techniques, and so forth. The requirements of the National Electrical Safety Code, the Underwriters’ Laboratories, and the American National Standards Institute may also be incorporated into the franchise ordinance by reference. Beyond these, communities may want to set local technical standards that exceed the FCC’s requirements in three principal areas:

- Television signal quality
- Reliability and maintainability
- Performance monitoring and testing

² Letter from Sol Schildhause, Chief of the FCC Cable Television Bureau, to Western Communications Inc., August 11, 1972.
Signal Quality

"Signal quality," a term derived from broadcast TV usage, relates to the picture and sound delivered to the viewer's TV set. Five categories, "excellent," "fine," "passable," "marginal," and "inferior," were established in 1959 by the Television Allocation Study Organization (TASO), an industry group set up at the FCC's request. Although some quantitative characteristics (e.g., signal-to-noise ratio) are involved, these are largely subjective measures, based on the viewer's reaction to the picture he sees.

For cable TV systems, many franchise ordinances have required "high quality" or "good quality" without defining these terms specifically. This simply invites argument over whether the franchise requirement is being met.

The FCC standards for Class I channels define a minimum signal-to-noise ratio, signal level and frequency tolerances, and other parameters that determine signal quality. If these quantitative standards are achieved and maintained, the presumption is that quality will be at least acceptable to most viewers. This presumption should be examined carefully.

Almost every component of a cable system introduces some perturbation to the original signal, and many of the effects are cumulative. The major problems are:

- Signals leaving the broadcast transmitter may degrade by the time headend antennas pick them off the air.
- Headend signal processing equipment with its concentration of electronic components may introduce degradation.
- Each amplifier in the cable system introduces two undesirable effects, "noise" and "distortion." Electrical noise consists of random disturbances (e.g., "static") introduced by all components in the path of current flow. Distortion arises because amplifiers do not amplify all portions of a signal in the same proportion. Thus the amplifier output is a distorted version of the input. Both effects being cumulative, subscribers at the far end of a trunk or feeder cable will not receive as good a picture as those closer to the headend.
- All connections to the cable network, whether simple subscriber taps or local origination facilities, introduce discontinuities that increase noise or distortion. The cable itself can act as a giant antenna, picking up faraway radio signals or minute noise sources.
- Set-top converters and TV set tuners are particularly troublesome sources of interference. Problems are aggravated when a cable carries more than 12 channels, since the 12 VHF channel frequencies were originally chosen to minimize interference.

Consequently, a city that wants to require better signal quality than the FCC rules demand must pay close attention to all aspects of cable system design. Simply tightening the FCC's quantitative standards may not suffice.

Almost all of the above sources of noise and distortion become much more critical for two-way systems, because subscriber-to-headend messages enter the cable at hundreds of points. Poor connectors, faulty splices, or careless grounding may funnel intolerable noise into the system.

Many one-way cable systems can tolerate relatively sloppy design and construction features, but two-way systems cannot. This fact is of special concern for systems built to offer one-way services initially, but with the capacity to expand into two-way
services at a later date. Unless the system is checked for two-way transmission at the outset, the expansion may require inordinate effort and cost.

Reliability and Maintainability

Reliability can be defined as the capability to maintain a consistent level of performance, once initially established. A system that works well when it is operative, but breaks down often, has good performance characteristics but poor reliability.

Maintainability is the ease with which a malfunction can be corrected, once it does occur. All complex electronic systems will have some failures, no matter how well designed, but good maintainability minimizes system "down time."

In the telephone, computer, and other technical industries, reliability and maintainability are defined quantitatively and written into specifications as a matter of routine. Reliability is usually quantified as a specified "mean-time-between-failure," and maintainability as "mean-time-to-repair." These are statistically averaged objectives against which actual performance is measured. They require precise definition of terms such as "failure," upon which there may be disagreement, but once defined they replace subjective terms with objective measurable ones.

Reliability and maintainability are becoming important for new major-market cable systems. Many projected nonbroadcast services will demand a level of reliability higher than the current standards of the cable industry. Business data communications, alarm and sensor monitoring services, and information retrieval cannot tolerate a high incidence of errors or equipment breakdown.

Even though these new services may not be offered for several years, if at all, franchising authorities must treat reliability as a current concern, because it is extremely difficult and expensive to "add" reliability to a system at a later date. Such basic construction and installation details as grounding, shielding, and the type of connectors used can intrinsically limit the reliability of the system. Thus, if high reliability is needed, it should be an inherent part of the original system design.

Two problems arise immediately. First, it is difficult to establish reliability and maintainability specifications for cable systems that are in a rapid stage of technological evolution. Second, many of the desirable specifications would be more costly than either the cable system operator or subscribers are currently prepared to pay for.

There are no quick solutions to these problems. Still, franchising authorities should include questions of reliability and maintainability in their considerations. Otherwise, they may foreclose many of the broadcast services that cable hopes to offer urban communities in the years ahead.

Performance Monitoring and Testing

Once technical performance or reliability standards have been established, the tasks of monitoring and assuring compliance follow. Many past franchises have included no monitoring provisions at all. Others have specified some performance testing, but without enforcement or penalty provisions.

The FCC rules require system performance tests to demonstrate compliance with federal technical standards. Once each year, the operator must test his system
at three widely separate points, including one at the far end of the network. The individual tests, procedures, and equipment used are the operator's responsibility, but they must receive FCC approval that they do, in fact, make all the measurements necessary to assure compliance.

The FCC requirements represent a large step forward in establishing a common baseline for major-market systems and guaranteeing that federal technical standards will be monitored annually.\(^3\) A number of uncertainties remain, however. First, testing a complex system at three points may not be a completely adequate indication of performance, particularly if the same three points are always selected. Second, there is no requirement for FCC or city personnel to supervise or even witness the tests. Third, the system presumably is acceptable if it passes the tests once during the year, regardless of its record of malfunction or reliability. To use an extreme and unrealistic example, a system meeting the standards on the day of the test would satisfy the FCC even if it were inoperative the rest of the year. Finally, no penalties are specified except the implication that tests would be repeated if technical standards are not being met. Presumably, the FCC could withdraw its certification of the system and thus deny it the right to carry broadcast signals, but this seems likely only as a last resort.

The question of appropriate penalties for noncompliance is of great concern to cities. In most past franchises, the only penalty provision was the threat of franchise cancellation. This "ultimate sanction" not only is inappropriate for minor system deficiencies, but usually does not even serve as a credible threat. To cancel a franchise, a city must establish a sound legal case of default on franchise requirements. This will be very difficult if the requirements themselves are imprecise and will, in any event, involve considerable delay. Cancellation is a last resort, then; it is next to useless in more normal situations where standards are partially met, or where minor improvements are needed.

If a city intends to write and enforce its own technical standards, a better approach is to specify the tests to be performed, as well as a range of compliance and penalty provisions. Tests should be conducted on a statistical sampling basis, with a large enough sample to demonstrate performance throughout the system (50 to 100 subscribers should be enough for a large system). At the simplest level, the test might consist of tuning the subscriber's TV set or converter through all channel positions and judging picture quality according to the subjective TASSO standard. Other, more quantitative tests can be devised for nonbroadcast services. The cable operator might perform the tests and certify them to the city. Alternatively, they could be conducted by outside consultants or by the city's own staff in much the same manner as building inspection now takes place. New York City recently established an Office of Telecommunication with a full-time director and staff to monitor cable system performance and handle subscriber complaints. Other cities are considering creating similar offices, whose expenses presumably would be provided out of franchise fees.

Table 12 illustrates this approach (in oversimplified form). A set of tests would be performed at the designated subscribers' TV sets, or at equivalent terminals connected to the system. Some percentage of substandard service would be allowed

\(^3\) The cable industry asked for and received a one-year stay of these performance testing requirements in 1972. They remain in effect for 1973 and beyond.
Table 12
EXAMPLE OF FRANCHISE COMPLIANCE AND PENALTY PROVISIONS:
10% SUBSTANDARD SERVICE ALLOWABLE

<table>
<thead>
<tr>
<th>% Terminals Not Meeting Specifications</th>
<th>Initial Test: Days to Implement Corrective Action</th>
<th>Retest: Fine for Noncompliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>Not required</td>
<td>---</td>
</tr>
<tr>
<td>10-20</td>
<td>60</td>
<td>$1,000</td>
</tr>
<tr>
<td>20-30</td>
<td>90</td>
<td>$5,000</td>
</tr>
<tr>
<td>30-40</td>
<td>120</td>
<td>$25,000</td>
</tr>
<tr>
<td>Above 40</td>
<td>(a)</td>
<td>(a)</td>
</tr>
</tbody>
</table>

*Consider franchise cancellation.*

(arbitrarily shown as 10 percent in Table 12). Thus if 45 out of 50 terminals passed the tests, no corrective action or penalty would apply. If more than 10 percent of the terminals tested did not meet specifications, the system operator would be given time to take corrective action. Retests would then be made. If the level of service were still substandard, the city would assess a series of fines (or rate reductions) based on the overall performance level. It might also specify that the system again be retested every six months until performance improved.

A similar schedule could be devised for system reliability and maintainability, perhaps giving the operator a certain amount of time to correct specified malfunctions. With this approach, the penalty seems more appropriate to the offense, and the threat of franchise cancellation is reserved for those situations where the city really means to carry it out.

PROBLEM AREAS

Technical standards provide a formalized response to the question, "How good should a cable TV system be?" To arrive at any sensible answer, another question must first be posed: "What is a cable TV system supposed to do?"

Conventional cable systems supply entertainment to subscribers by redistributing broadcast TV (and sometimes radio) programs. This has been the only source of revenue in the past and promises to be the major (if not the only) source in the immediate future. Consequently, commercial cable operators design their systems today primarily for entertainment services. They naturally resist additional technical requirements that will increase system costs without offering compensating revenues. They often conclude it will be financially advantageous if they wait till later to install new equipment and tighten system specifications, even if it costs much more to retrofit than to build in these features at the start. Businessmen place a greater time value on money (i.e., discount rate) than do most government officials or policy analysts.

Cities and community organizations, on the other hand, may place priority on nonentertainment services. They may want technical standards written to insure
that the cable system can provide additional education channels, data links among city hospitals, and interactive services to the home. Their interest has been fueled by years of glowing predictions of cable's vast potential for improving urban communications.4

The FCC regulations bring some comfort to both views, and also some confusion. Requiring that 50 percent of the total channel capacity be reserved for nonbroadcast use is an attempt to encourage major market cable TV systems to provide new, nonentertainment services. At the same time, establishing technical standards only for Class I channels is no help to cities that might want to lay at least the groundwork for implementation of new services in the future. Introduction of new services may, in fact, be delayed if the initial system design is based only on the FCC standards.

The heart of the problem is that a cable system good enough for TV entertainment may simply not be good enough for many nonentertainment services.

Communities have no easy solutions to turn to. Since most new services are, by definition, untested at this time, franchising authorities cannot specify a cable system design that will meet all future requirements. The more flexibility and the more stringent standards they require, the more the system will cost above one oriented primarily toward entertainment services.

Most cities have not faced the question of who will pay this additional cost. Since many proposed new applications will serve education, health care, public safety, and other public needs, a city should be prepared to share the cost of system upgrading with the cable system operator. If the cost burden is apportioned equitably, a city can then in good conscience expect and specify the levels of performance and reliability these new functions will require.

If, on the other hand, the added system cost cannot be justified initially, franchising authorities should at least be aware that many future services may be diminished in scope or foreclosed entirely. These considerations should be explored during planning and franchising, not after a franchise award.5

Even without considering the added cost of a higher quality system, the cost of monitoring a cable system for compliance with technical standards can easily exceed city revenue from franchise fees. A 20,000-subscriber system with subscriber rates of $72 per year will gross $1,440,000 a year. At the FCC-preferred rate of 3 percent, the city's annual franchise fee would amount to $43,200. This might support only one or two full-time technicians, with equipment, supervision, and overhead added. Consequently, cities must carefully add up the costs and benefits of an active local regulatory program, lest its cable system become an unforeseen revenue drain rather than a new source of income.

4 For example, see the report of the Committee on Telecommunications, Communications Technology for Urban Improvement, National Academy of Engineering, Washington, D.C., 1971.

Appendix

FCC TECHNICAL STANDARDS FOR CABLE SYSTEMS

Subpart K—Technical Standards

§ 76.601 Performance tests.
(a) The operator of each cable television system shall be responsible for ensuring that each such system is designed, installed, and operated in a manner that fully complies with the provisions of this subpart. Each system operator shall be prepared to show, on request by an authorized representative of the Commission, that the system does, in fact, comply with the rules.

(b) The operator of each cable television system shall maintain at its local office a current listing of the cable television channels which that system delivers to its subscribers and the station or stations whose signals are delivered on each Class I cable television channel, and shall specify for each subscriber the minimum visual signal level it maintains on each Class I cable television channel under normal operating conditions.

(c) The operator of each cable television system shall conduct complete performance tests of this system at least once each calendar year (at intervals not to exceed 14 months) and shall maintain the resulting test data on file at the system's local office for at least five (5) years. It shall be made available for inspection by the Commission on request. The performance tests shall be directed at determining the extent to which the system complies with all the technical standards set forth in § 76.605. The tests shall be made on each Class I cable television channel specified pursuant to paragraph (b) of this section, and shall include measurements made at no less than three widely separated points in the system, at least one of which is representative of terminals most distant from the system input in terms of cable distance. The measurements may be taken at convenient monitoring points in the cable network: Provided, That data shall be included to relate the measured performance to the system performance as would be viewed from a nearby subscriber terminal. A description of instruments and procedure and a statement of the qualifications of the person performing the tests shall be included.

(d) Successful completion of the performance tests required by paragraph (c) of this section does not relieve the system of the obligation to comply with all pertinent technical standards at all subscriber terminals. Additional tests, repeat tests, or tests involving specified subscriber terminals may be required by the Commission in order to secure compliance with the technical standards.

(e) All of the provisions of this section shall become effective March 31, 1972.

§ 76.605 Technical standards.
(a) The following requirements apply to the performance of a cable television system as measured at any subscriber terminal with a matched termination, and to each of the Class I cable television channels in the system:

(1) The frequency boundaries of cable television channels delivered to subscriber terminals shall conform to those set forth in § 73.603(a) of this chapter: Provided, however, That on special application including an adequate showing of public interest, other channel arrangements may be approved.

(2) The frequency of the visual carrier shall be maintained 1.25 MHz±25 kHz above the lower boundary of the cable television channel, except that, in those systems that supply subscribers with a converter in order to facilitate delivery of cable television channels, the frequency of the visual carrier at the output of each such converter shall be maintained 1.25 MHz±250 kHz above the lower frequency boundary of the cable television channel.

(3) The frequency of the aural carrier shall be 4.5 MHz±1 kHz above the
frequency of the visual carrier.

(4) The visual signal level, across a terminating impedance which correctly matches the internal impedance of the cable system as viewed from the subscriber terminals, shall be not less than the following appropriate value:

Internal impedance: 75 ohms.
300 ohms.

Visual signal level: 1 millivolt. 2 millivolts.

(At other impedance values, the minimum visual signal level shall be \(0.0133\) Z millivolts, where Z is the appropriate impedance value.)

(5) The visual signal level on each channel shall not vary more than 12 decibels overall, and shall be maintained within:

(1) 3 decibels of the visual signal level of any visual carrier within 6 MHz nominal frequency separation, and

(2) 12 decibels of the visual signal level on any other channel, and

(3) A maximum level such that signal degradation due to overloading in the subscriber's receiver does not occur.

(6) The rms voltage of the aural signal shall be maintained between 13 and 17 decibels below the associated visual signal level.

(7) The peak-to-peak variation in visual signal level caused undesired low frequency disturbances (hum or repetitive transients) generated within the system, or by inadequate low frequency response, shall not exceed 5 percent of the visual signal level.

(8) The channel frequency response shall be within a range of ±2 decibels for all frequencies within 

(9) The ratio of visual signal level to system noise, and of visual signal level to any undesired cochannel television signal operating on proper offset assignment, shall be not less than 36 decibels. This requirement is applicable to:

(1) Each signal which is delivered by a cable television system to subscribers within the predicted Grade B contour for that signal, or

(10) The ratio of visual signal level to the rms amplitude of any coherent disturbance or discrete-frequency interfering signals not operating on proper offset assignments shall not be less than 46 decibels.

(11) The terminal isolation provided each subscriber shall be not less than 18 decibels, but in any event, shall be sufficient to prevent reflections caused by open-circuited or short-circuited subscriber terminals from producing visible picture impairments at any other subscriber terminals.

(12) Radiation from a cable television system shall be limited as follows:

<table>
<thead>
<tr>
<th>Frequency Limit (microvolts)</th>
<th>Distance Limit (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to and including 34 MHz...</td>
<td>15</td>
</tr>
<tr>
<td>Over 34 up to and including 220 MHz</td>
<td>25</td>
</tr>
<tr>
<td>Over 220 MHz...</td>
<td>15</td>
</tr>
</tbody>
</table>

(b) Cable television systems distributing signals by using multiple cable techniques or specialized receiving devices, and which, because of their basic design, cannot comply with one or more of the technical standards set forth in paragraph (a) of this section, may be permitted to operate provided that an adequate showing is made which establishes that the public interest is benefited. In such instances the Commission may prescribe special technical requirements to ensure that subscribers to such systems are provided with a good quality of service.

(c) Paragraph (a)(12) of this section shall become effective March 31, 1972. All other provisions of this section shall become effective in accordance with the following schedule:

<table>
<thead>
<tr>
<th>Date</th>
<th>Effective date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar. 31, 1977</td>
<td>Cable television systems commencing operations on or after March 31, 1972.</td>
</tr>
</tbody>
</table>

§ 76.609 Measurements.

(a) Measurements made to demonstrate conformity with the performance requirements set forth in §§ 76.701 and 76.605 shall be made under conditions which reflect system performance during normal operations, including the effect of any microwave relay operated in the Cable Television Relay (CARR) Service intervening between pickup antenna and the cable distribution network. Amplifiers shall be operated at normal gains, either by the insertion of appropriate signals or by manual adjustment. Special signals inserted in a cable television channel for measurement purposes should be operated at levels approximating those used for normal operation. Pilot tones, auxiliary or substitute signals, and non-television signals normally carried on the cable television system should be operated at normal levels to the extent possible, but not mandatory, measurement procedures are set forth in this section.

(b) When it may be necessary to remove the television signal normally carried on a cable television channel in order to facilitate a performance measurement, it will be permissible to disconnect the antenna which serves the channel. Other antennas and inputs should remain connected and normal signal
levels should be maintained on other channels.

(e) As may be necessary to ensure satisfactory service to a subscriber, the Commission may require additional tests to demonstrate system performance or may specify the use of different test procedures.

(d) The frequency response of a cable television channel may be determined by one of the following methods, as appropriate:

1. By using a swept frequency or a manually variable signal generator at the sending end and a calibrated attenuator and frequency-selective voltmeter at the subscriber terminal.

2. By using a multiburst generator and modulator at the sending end and a demodulator and oscilloscope display at the subscriber terminal.

(e) System noise may be measured using a frequency-selective voltmeter (field strength meter) which has been suitably calibrated to indicate rms noise or average power level and which has a known bandwidth. With the system operating at normal level and with a properly matched resistive termination substituted for the antenna, noise power indications at the subscriber terminal are taken in successive increments of frequency equal to the bandwidth of the frequency-selective voltmeter, summing the power indications to obtain the total noise power present over a 4 MHz band centered within the cable television channel. If it is established that the noise level is constant within this bandwidth, a single measurement may be taken which is corrected by an appropriate factor representing the ratio of 4 MHz to the noise bandwidth of the frequency-selective voltmeter. If an amplifier is inserted between the frequency-selective voltmeter and the subscriber terminal in order to facilitate this measurement, it should have a bandwidth of at least 4 MHz and appropriate corrections must be made to account for its gain and noise figure. Alternatively, measurements made in accordance with the NCTA standard on noise measurement (NCTA Standard 005-0563) may be employed.

(f) The amplitude of discrete frequency interfering signals within a cable television channel may be determined with either a spectrum analyzer or with a frequency-selective voltmeter (field strength meter), which instruments have been calibrated for adequate accuracy. If calibration accuracy is in doubt, measurements may be referenced to a calibrated signal generator, or a calibrated variable attenuator, substituted at the point of measurement. If an amplifier is used between the subscriber terminal and the measuring instrument, appropriate corrections must be made to account for its gain.

(g) The terminal isolation between any two terminals in the system may be measured by applying a signal of known amplitude to one and measuring the amplitude of that signal at the other terminal. The frequency of the signal should be close to the midfrequency of the channel being tested.

(h) Measurements to determine the field strength of radio frequency energy radiated by cable television systems shall be made in accordance with standard engineering procedures. Measurements made on frequencies above 25 MHz shall include the following:

1. A field strength meter of adequate accuracy using a horizontal dipole antenna shall be employed.

2. Field strength shall be expressed in terms of the rms value of synchronizing peak for each cable television channel for which radiation can be measured.

3. The dipole antenna shall be placed 10 feet above the ground and positioned directly below the system components. Where such placement results in a separation of less than 10 feet between the center of the dipole antenna and the system components, the dipole shall be repositioned to provide a separation of 10 feet.

4. The horizontal dipole antenna shall be rotated about a vertical axis and the maximum meter reading shall be used.

5. Measurements shall be made where other conductors are 10 or more feet away from the measuring antenna.

§ 76.613 Interference from a cable television system.

In the event that the operation of a cable television system causes harmful interference to reception of authorized radio stations, the operation of the system shall immediately take whatever steps are necessary to remedy the interference.

§ 76.617 Responsibility for receiver-generated interference.

Interference generated by a radio or television receiver shall be the responsibility of the receiver operator in accordance with the provisions of Part 15, Subpart C, of this chapter. Provided, however, that the operator of a cable television system to which the receiver is connected shall be responsible for the suppression of receiver-generated interference that is distributed by the system when the interfering signals are introduced into the system at the receiver.