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ABSTRACT

The technology of cable television is advancing rapidly. Of prime importance to cable television in the 1970s will be the development of two-way interactive communication services on cable systems. This report describes that development; the technical, economic, and regulatory forces that influence it; and the public policy issues that it raises. This report has been written for several distinct groups of readers. Those concerned chiefly with broad policy questions may wish to read only the summary, the introduction, and the final section on policy issues posed by the evolution of two-way services on cable. Readers who want a more detailed description of potential services, including the "subscriber response services" that seem most likely to be feasible in the next five years, should also read Sections II and III. Those interested in the near-term economics of this group of services should focus on Section IV. Finally, readers interested in the present status of two-way cable television will find a discussion of recent field tests and demonstrations in Section V. (Author)

R-888-MF

November 1971

INTERACTIVE TELEVISION
Prospects for Two-Way Services on Cable

Walter S. Baer

A Report prepared under a Grant from

THE JOHN AND MARY R. MARKLE FOUNDATION

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PREFACE

The technology of cable television is advancing rapidly. Of prime importance to cable television in the 1970s will be the development of two-way interactive communication services on cable systems. This report describes that development; the technical, economic, and regulatory forces that influence it; and the public policy issues that it raises.

This report has been written for several distinct groups of readers. Those concerned chiefly with broad policy questions may wish to read only the summary, the introduction, and the final section on policy issues posed by the evolution of two-way services on cable. Readers who want a more detailed description of potential services, including the "subscriber response services" that seem most likely to be feasible in the next five years, should also read Sections II and III. Those interested in the near-term economics of this group of services should focus on Section IV. Finally, readers interested in the present status of two-way cable television will find a discussion of recent field tests and demonstrations in Section V.

The research on which this report is based has been conducted under a three-year grant to Rand from The John and Mary R. Markle Foundation for the study of communications policy issues. The initial phase of this research was also supported by The Ford Foundation as part of a broader study of the feasibility of cable television in Washington, D.C. The Rand work in Washington was undertaken in close cooperation with The MITRE Corporation, McLean, Virginia.

SUMMARY

Discussions of the future of cable television often present glowing pictures of potential two-way communications services on cable. Extensive lists of new services have been compiled. Commercial services such as security alarm monitoring, remote shopping, and computer-to-computer data transmission are typically cited as important to the economic success of cable television in cities. In addition, it is claimed that non-commercial services, such as interactive educational television in the home and direct citizen feedback on local political issues, would be of great public benefit. Impressed with these possibilities, the Federal Communications Commission has recently proposed that two-way transmission capacity be installed in all cable systems in the hundred largest U.S. television markets.

As is often the case with emerging technologies, however, the promise of two-way services on cable has at times been oversold. Although most proposed new services are technically feasible, many will not be economically feasible for at least a decade. Others can probably be best accommodated on the telephone network or by other means. Some may not be desirable at all. The value to society of, and the commercial demand for, various new cable services is, in general, unknown at the present time.

Meeting the FCC's proposed requirement for two-way transmission capacity will add between 15 and 30 percent to the capital cost of a single cable, one-way distribution plant. Transmitting two-way signals at different frequencies on the same cable, or using separate cables for signals in each direction, are the principal techniques that will be used. Providing two-way capacity is, however, very different from providing two-way services. The latter requires a considerable investment in equipment at a central facility and at each subscriber's location. Subscriber terminal equipment will in fact represent the bulk of added capital costs for all large two-way systems. Eventually, programming and other software costs will be greater than hardware expenditures if two-way cable services prove successful.

This study groups proposed cable services according to their technical requirements and the estimated capital costs to provide them. Interactive services are separated into four categories:

- <u>Subscriber response services</u>, such as opinion polling or alarm monitoring, in which individual subscribers (or equipment installed at their locations) send short data responses to queries from a central point.
- <u>Shared voice and video services</u>, such as instructional television with voice feedback, in which individuals share return channels to a central point.
- <u>Subscriber initiated services</u>, such as catalog ordering or ticket sales, in which individuals can request information or service from a variety of sources.
- <u>Point-to-point services</u>, in which one subscriber transmits video, voice, or data information directly to another.

On the basis of the projected cost for subscriber terminal equipment alone, subscriber initiated and point-to-point services appear too costly for mass home audiences in this decade, although some business and institutional uses may be feasible. Formidable problems in developing computer software for subscriber initiated services can also be expected.

Subscriber response services, perhaps with shared voice return channels, seem more likely candidates for home use in the next five years. The investment cost for the basic two-way equipment required would amount to roughly \$150-\$340 per subscriber, over and above the \$125 per subscriber calculated for conventional one-way cable service. Two-way services that could be provided with this equipment include audience counting for advertisers and programmers, remote shopping, interactive entertainment and instructional programming, opinion polling, and selection of subscription or limited access channels. Other response services such as meter reading, fire alarm monitoring, and environmental monitoring would require additional equipment. More sophisticated and costly services such as information retrieval and computer-aided instruction could be added to the basic response system as they prove feasible.

With this capital investment and reasonable assumptions about operating costs, a cable operator would need additional monthly revenues of between $4.50 and $13.00 per subscriber to break even on two-way response services. This means doubling or tripling his present monthly revenue from one-way television distribution. Most of the added revenue would have to come from increased monthly subscriber fees, although advertisers, business firms, utilities, schools, and government users would pay for services of benefit to them. Expected revenues from specific services cannot be estimated at the present time, since no real field experience or evidence of consumer demand is yet available. Providing a mix of response services supported by home subscribers, business, and government users appears to be a better strategy for the cable operator than supplying a single service alone.

Several cable systems began field tests of two-way transmission in 1971. These tests indicate that two-way transmission on a single cable is indeed feasible but will require greater attention to system design and construction than has been the industry practice to date. Tighter standards for system components and installation procedures will be necessary. Moreover, building two-way capability into a cable system from the beginning is considerably easier than retrofitting an existing one-way system. Even without an FCC requirement, most large cable operators are likely to include two-way capability in new urban systems.

The FCC's proposed rules, then, would make uniform an industry trend toward provision of two-way capability in major market cable systems. Since the widespread acceptance of two-way cable services will require step-by-step development over a number of years, the Commission and other concerned parties have time to consider the several policy issues raised by this new technology. These issues include the development of technical standards, protection of individual privacy, and definition of the role of the cable operator as common carrier or direct provider of two-way services.

The wisest policy today would be to let two-way cable services develop in the marketplace under the FCC's proposed rules. Cable systems should be relatively free to experiment with a variety of service offerings and customer charges. Additional regulatory constraints can be imposed, if necessary, when the economic and social importance of these services becomes better known. Moreover, there are at present no convincing arguments for widespread public subsidy of two-way cable services. But some public support for field tests of community services, such as interactive instructional programming and direct citizen response, would be worthwhile in order to help determine what public benefits can be expected from two-way cable technology.

ACKNOWLEDGMENTS

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OTHER RAND REPORTS ON CABLE TELEVISION

This is one of a series of publications in Rand's Communications Policy Program. Previous reports include:

Leland L. Johnson, The Future of Cable Television: Some Problems of Federal Regulation, RM-6199-FF, January 1970.

Richard A. Posner, Cable Television: The Problem of Local Monopoly, RM-6309-FF, May 1970.

N. E. Feldman, Cable Television: Opportunities and Problems in Local Program Origination, R-570-FF, September 1970.

Rolla Edward Park, Potential Impact of Cable Growth on Television Broadcasting, R-587-FF, October 1970.

Leland L. Johnson, Cable Television and the Question of Protecting Local Broadcasting, R-595-MF, October 1970.

Rolla Edward Park, Cable Television and UHF Broadcasting, R-689-MF, January 1971.

Leland L. Johnson, Cable Television and Higher Education: Two Contrasting Experiences, R-828-MF, September 1971.

Michael R. Mitchell, State Regulation of Cable Television, R-783-MF, October 1971.

Rolla Edward Park, Prospects for Cable in the 100 Largest Television Markets, R-875-MF, October 1971.

Information on these and other Rand publications may be obtained by writing to:

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I. INTRODUCTION

Cable television has evolved over the past two decades as a distributor of conventional television programming. While information on the cable now flows one way -- from the antenna or "headend" to the home -- cable system operators and others have talked for years about interactive, two-way communications services over cable networks. The technology to provide such services is here today. But despite much rhetoric and enthusiastic projections of future broadband communication systems, very little has happened. At present, probably fewer than fifty of the more than 5.5 million cable television subscribers in the United States are equipped for any kind of interactive services.

CABLE GROWTH IN CITIES

The emergence of two-way communications over cable systems will be closely related to the growth of cable in the major U.S. television markets. Up to now, cable television has been most successful in places where over-the-air reception is poor, and in towns and rural areas where only a few broadcast television signals are otherwise available. There has been little penetration of cable into the large cities.

The regulatory policy of the Federal Communications Commission, which has to date forbidden cable operators in the 100 largest markets from distributing signals brought in from other cities, has been considered the chief barrier to cable growth in urban areas.[1] The Commission, in its long-awaited proposed rules for cable, announced on August 5, 1971 that it would somewhat relax these restrictions on distant signal importation. But as part of the rulemaking package, the Commission stated:

> After studying the comments received and our own engineering estimates, we have decided to require that there be built into cable systems the capacity for two-way communication. This is apparently now feasible at

[1] Leland L. Johnson, The Future of Cable Television: Some Problems of Federal Regulation, RM-6199-FF, The Rand Corporation, January 1970.

a not inordinate additional cost, and its availability is essential for many of cable's public services. Such two-way communication, even if rudimentary in nature, can be useful in a host of ways -- for surveys, marketing services, burglar alarm devices, educational feed-back, to name a few.[1]

Thus a two-way communications capability for cable systems in the largest markets will be required if the FCC's proposed rules are adopted. It also may turn out to be a commercial necessity for the success of urban cable systems. For even if cable systems are allowed to carry distant signals, it is not at all clear how much this will stimulate demand for cable in cities where several television channels already are available and reception is tolerably good. A recent Rand report suggests that only 20 to 35 percent of households in the top 100 markets would subscribe to cable under the rules for distant signal importation proposed in the FCC Letter.[2]

Some observers look to local program origination and the sale of local advertising by cable systems as a key to the successful penetration of cable in major cities.[3] Yet few cable operators today share that view. Except for sports and other special events programs, operators see local origination as a net drain on their cash flow rather than as a primary source of new subscribers and revenues. So far, local program origination has not provided significant earnings for cable operators outside major market areas.[4]

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[1] Letter from Dean Burch, Chairman of the Federal Communications Commission, to Senator John Pastore, Chairman of the Senate Communications Subcommittee, August 5, 1971, p. 31. Henceforth referred to as the FCC Letter.

[2] R. E. Park, Prospects for Cable in the 100 Largest Television Markets, R-875-MF, The Rand Corporation, October 1971.

[3] Some recent proprietary studies of the cable television industry take this point of view. See also the Comments on Mandatory Origination and Maximum Public Benefit from Cable Services, Central ACCESS, Inc., FCC Docket No. 18397, 1970.

[4] N. E. Feldman, Cable Television: Opportunities and Problems in Local Program Origination, R-595-MF, The Rand Corporation, October 1970; and D. Anderson, "Experienced Perspective on the Origination 'Bug'," TV Communications, March 1971.

The other stimulus to demand for cable television in cities would be the development of two-way communication services. A broadband cable obviously can transmit other information besides television signals. With its tremendous potential capacity, cable operators hope to satisfy growing needs for information in business, government, and the home. Extensive lists of interactive services that could be provided by cable television systems have been compiled. Table 1 presents some of these potential applications -- unsorted as to social usefulness and economic feasibility on cable systems. Such lists could be extended nearly indefinitely.

Development of these new services, or any significant subset of them, could stimulate the rapid and profitable growth of cable systems in cities. Individuals who would not subscribe for marginally better television reception and program variety might well pay for home security surveillance, remote shopping, and other special services. Business and government users might subscribe to services tailored specially for them. The result, according to the chief executive of the largest cable television operator in the country, will be that "Five years from now we'll be getting less than 25 percent of our cable revenue from the services we're providing today."[1] Yet today, consumer demand for these services is completely unproved in the marketplace.

The question of cable system profitability in cities is important to others besides entrepreneurs and stockholders. Much has been said and written about the public benefits to be derived from cable communications. The commentators generally believe that city dwellers, particularly low-income city dwellers, can be the principal beneficiaries of cable technology. High-capacity cable communication systems could provide low-cost channels for dissemination of job information; information on health care, welfare, and other city services; preschool

[1] Irving Kahn, Chairman of TelePrompTer Corporation, quoted in J. Kronenburger, "Cable: Shape of Things to Come?" Look, September 9, 1971, p. 66.

Table 1

SOME PROPOSED INTERACTIVE SERVICES FOR CABLE TELEVISION[a]

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

[a]These services are not all likely to 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.

education programs; and instruction of all sorts.[1] They might help city governments be more responsive to individuals while performing more efficiently. Most important, in their view, new communication systems might contribute to a sense of community identity and community participation, "a means...to rebuild, in a sociological sense, the crowded inner core of major cities."[2] Without debating the value of community services or programming distributed by cable, obviously no public benefits can accrue until the community is wired to receive them. And unless large public subsidies become available to wire urban areas,[3] cable will be installed only when the system operator believes he can (at least in the long run) turn a profit.

THE BROADBAND COMMUNICATIONS NETWORK

Providing the limited two-way capability required by the FCC's proposed rules is only the beginning of possible new uses for cable communications. Further on is the vision of cable "information utilities" bringing picture, voice, and text material to the home at

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[1] H. S. Dordick, L. G. Chester, S. I. Firstman, and R. Bretz, Telecommunications in Urban Development, RM-6069-RC, The Rand Corporation, July 1969; and Committee on Telecommunications, National Academy of Engineering, Communications Technology for Urban Improvement, Report to the Department of Housing and Urban Development, June 1971.

[2] Ad Hoc Committee of the Industrial Electronics Division, The Future of Broadband Communications, Electronic Industries Association, the IED/EIA response to the Federal Communications Commission Docket 18397, Part V, October 1969, p. 4.

[3] Several forms of public subsidy to accelerate cable growth in low-income areas have been discussed in recent months. These include direct Federal agency grants, low-interest government loans or loan guarantees, and the issuance of tax free municipal or state bonds. However, one facet of the debate over distant signal importation has been the cable industry's insistence that cable systems in major markets would thrive if restrictions on signal importation were removed. It is thus difficult to justify any public subsidy for them. Rather, the industry seems to have convinced public officials that cable system operations will be a lucrative source of tax revenue for hard-pressed city governments. In the short run at least, both industry and government expectations may be overly optimistic.

the individual subscriber's request.[1] Cable systems could evolve into a nationwide, interconnected, two-way communications network independent of the present telephone system -- the "broadband communications network" outlined by the Electronics Industry Association (EIA), or the "wired nation."[2] To use the EIA's words, this would be "a revolution in communications which will produce a profound change in the way society is structured and in the way we live."[3]

PURPOSE OF THIS REPORT

But will it happen? Or, how do we get from here to there? Two-way services on cable television systems may not be commercially successful for many years. As one company president put it recently, "I don't know of a single CATV community where a cable operator can afford to build a complete two-way headend-to-home communications system today and make it pay off."[4] Moreover, the true community benefits from two-way cable services may be small or negligible in the next several years. Although the long-term potential of communications technology may be enormous, the short-term social benefits certainly have been oversold in some quarters.

This report, then, explores the likely evolution of cable television systems toward a broader communication capability and suggests some probable first steps in the next five years. Section II looks more closely at two-way communications via cable, discusses the technical requirements for potential new services, and focuses on a group described as "narrowband subscriber response services." Section III discusses

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[1] See, for example, The Information Utility and Social Choice, H. Sackman and N. Nie (eds.), AFIPS Press, Montvale, New Jersey, 1970.

[2] Ralph Lee Smith, "The Wired Nation," The Nation, May 18, 1970.

[3] The Future of Broadband Communications, p. 23. Of course, any such "profound change" would involve costs as well as benefits to society. A national, fully interconnected broadband communications network would pose questions of access, privacy, and control far beyond those discussed in this study for the more rudimentary services likely in the next few years.

[4] G. M. Nathanson, paper delivered at the 1971 National Cable Television Association convention, Washington, D.C., July 5-9, 1971 (proceedings to be published).

four such services -- audience counting, direct viewer response, special channel selection, and sensor surveillance -- that would be possible with a narrowband response system. Section IV discusses the economics of subscriber response services in more detail. It examines the cost of providing these services and the added revenues necessary to support them but does not try to estimate the consumer demand for them. Section V discusses the very limited experience to date with two-way cable television services. Some policy issues are outlined in Section VI, along with a recommendation for larger scale field tests of interactive services to better understand their potential importance.

II. THE SPECTRUM OF NEW SERVICES FOR CABLE

The term "two-way communications" applied to cable television systems encompasses a tremendous range of possible uses and services. This section considers the many proposed new services listed in Section I and attempts to distinguish those with common technical requirements. Six broad groupings are developed:

- one-way broadcast services
- one-way addressed services
- subscriber response services
- shared voice and video channels
- subscriber initiated services
- point-to-point services

Subscriber equipment costs for each group are estimated and compared. On the basis of subscriber equipment cost alone, one-way broadcast services, subscriber response services, and shared channel services appear more feasible in this decade for mass home audiences than the other service groups. In particular, information retrieval and other subscriber initiated services must await the development of low-cost, reliable terminals before they become attractive to home subscribers. Some difficult system design and software problems must also be overcome before subscriber initiated services can be offered on a mass basis.

SOME TECHNICAL PARAMETERS FOR TWO-WAY CABLE COMMUNICATIONS

All cable communication services obviously involve flows of information to and from certain points on the cable network. A number of factors then determine the technical requirements and costs for implementing them. Which points on the network are to send and receive signals? Who initiates and controls requests for service? How will signals to and from individual subscribers be kept separate? How much information must be transmitted in each direction? What equipment is required at each terminal point? What kinds of programming and software must be available to make each service feasible?

Network Configuration

One-way cable television systems distribute signals from a central point -- the headend -- to many subscribers over a party-line or "tree" network (Figure 1a). Everyone receives the same "downstream" signals on his cable at the same time.[1] This is in marked contrast to the switched telephone system in which each individual subscriber has his own "dedicated" wire pair that runs to the local switching office (Figure 1b).

Two-way cable television services require information flow "upstream" from the subscriber to the headend or among subscribers themselves. If these services are made available at a relatively few locations, or if a few subscribers make extensive use of two-way channels, either dedicated or point-to-point return links can be set up to serve them. For example, a point-to-point two-way cable network, shown schematically in Figure 1c, could interconnect schools, hospitals, and local government facilities in cities.[2] Still, point-to-point or switched cable installations appear quite expensive today when several thousand homes are to be wired for two-way services.[3] Thus, most cable television

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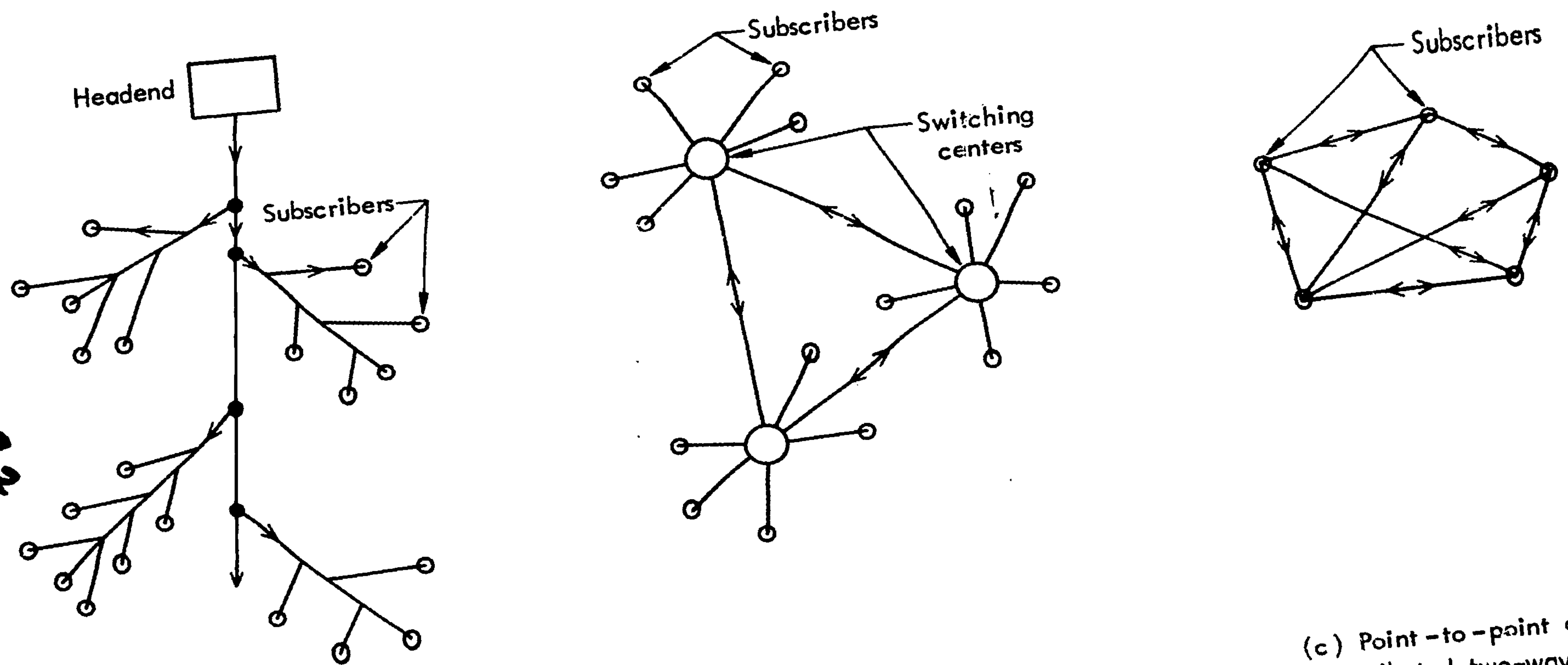
[1]Some cable systems make special programming or subscription channels available on a selective basis. Usually this is done by carrying the special channels at frequencies that the ordinary television set does not receive, and installing frequency converters only for certain subscribers.

[2]Communications Technology for Urban Improvement, p. 31. Uses of such a point-to-point network in a specific city -- Washington, D.C. -- are now being studied by the MITRE Corporation, McLean, Virginia.

[3]At least two companies, Rediffusion International, Limited and Ameco, Inc., offer switched broadband systems for television distribution. These systems may be attractive for providing 20 or more one-way video channels, particularly under high ambient signal level conditions. Either system also can be adapted for two-way communications; however, either one would cost considerably more than a conventional, tree-like cable network with return capability (see Section IV). Thus, neither system is likely to be installed for its two-way capability alone.

A principal deterrent to the growth of switched broadband communications in the United States is the highly developed North American telephone network. This switched narrowband network can provide some of the two-way services listed in Table 1 at low marginal cost today and will compete for many others as switched videophone services are developed. If one were building a communications system de novo, a



(a) One way, party-line or "tree" network

(b) Switched two-way network

(c) Point-to-point or distributed two-way network

Fig. 1 — Communication network configuration

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systems are expected to adopt shared party-line transmission facilities for upstream as well as downstream signals.

System Control

Proposed services differ markedly in technical design and cost depending on whether they are initiated and controlled by the user or by the system. For example, television ratings or "audience counting" involves monitoring the on-off and channel status of television receivers, but without need for direct subscriber response. Audience counting would be initiated and controlled from the headend, as would meter reading, alarm detection, and other sensor monitoring. Electronic delivery of periodicals and documents also would be controlled from the headend according to a regular schedule. On the other hand, information retrieval, computer data transmission, and facsimile services presumably would be initiated by the subscriber.

Services in which the subscriber responds to information presented on the screen can be under system control. Shopping from the home, for example, might be triggered by a televised advertisement for a local camera sale inviting viewers to place their orders directly. Each participating subscriber's terminal could then be polled in turn to determine if (a) he was watching the channel on which the advertisement appeared, and (b) he had responded with an order to purchase. The subscriber would be freely responding (or not responding) as he chose, but his response would follow system-controlled programming and be interpreted by the system in a predetermined manner. Responding to public opinion surveys, interactive educational programs, and TV games would be handled in a similar manner. In contrast, catalog ordering or using a remote computer for home calculations generally would be at the subscriber's initiative, independent of the programs currently shown on the screen.

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single, fully switched, 6 megahertz broadband network would be quite attractive. But given the present $50 billion-plus investment in telephone plant (approximately $500 per terminal), and Federal regulatory policy separating telephone and cable television ownership, the technical paths of the two industries are not likely to converge in this decade.

System initiated services are generally much easier to design and operate than subscriber initiated ones. Subscribers can be queried one by one, with each incoming response in proper sequence and format. With subscriber initiated services, however, the system must cope with parallel requests for a variety of services, each demanding different kinds of information at different data rates. Queueing, scheduling, and the use of multiple data bases usually pose severe problems. Similar difficulties have limited computer time-sharing systems to perhaps a thousand terminals at most.

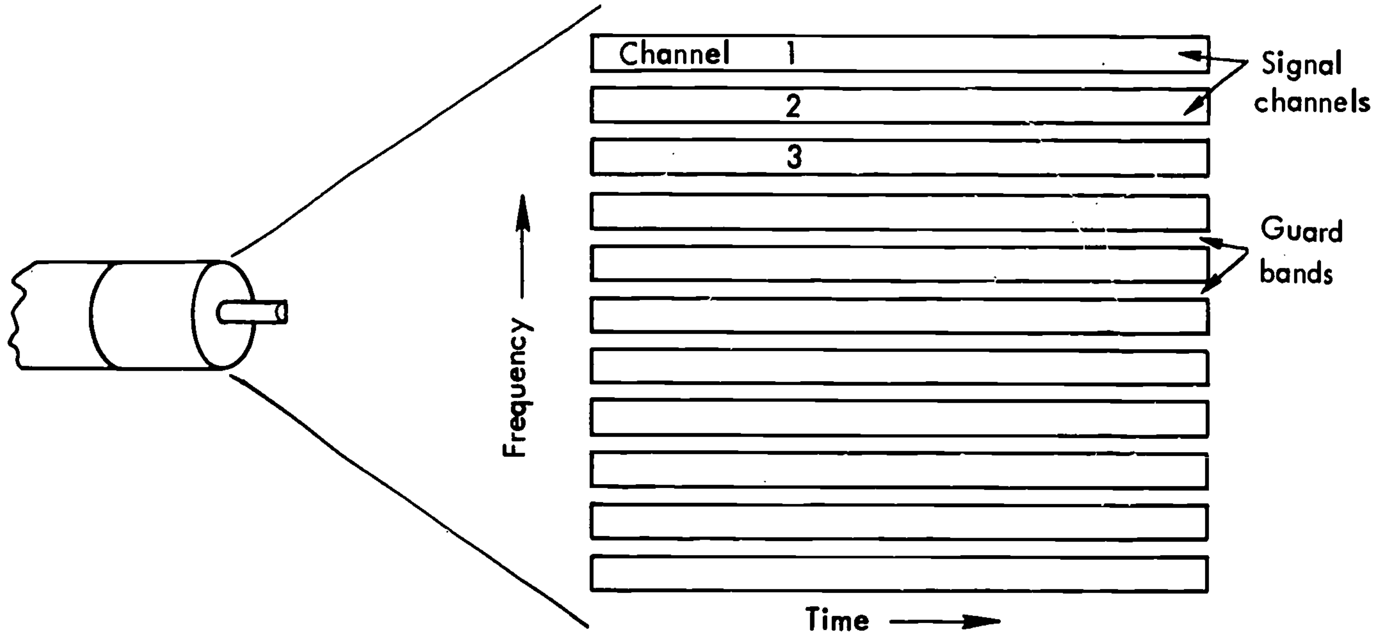
Multiplexing

Many two-way services require individually addressed inquiries and responses. This implies splitting, or "multiplexing," the transmission channels in two ways. First, the upstream channels must be multiplexed to distinguish signals from each individual subscriber. Second, the upstream and downstream channels must be kept separate to avoid interference between them.

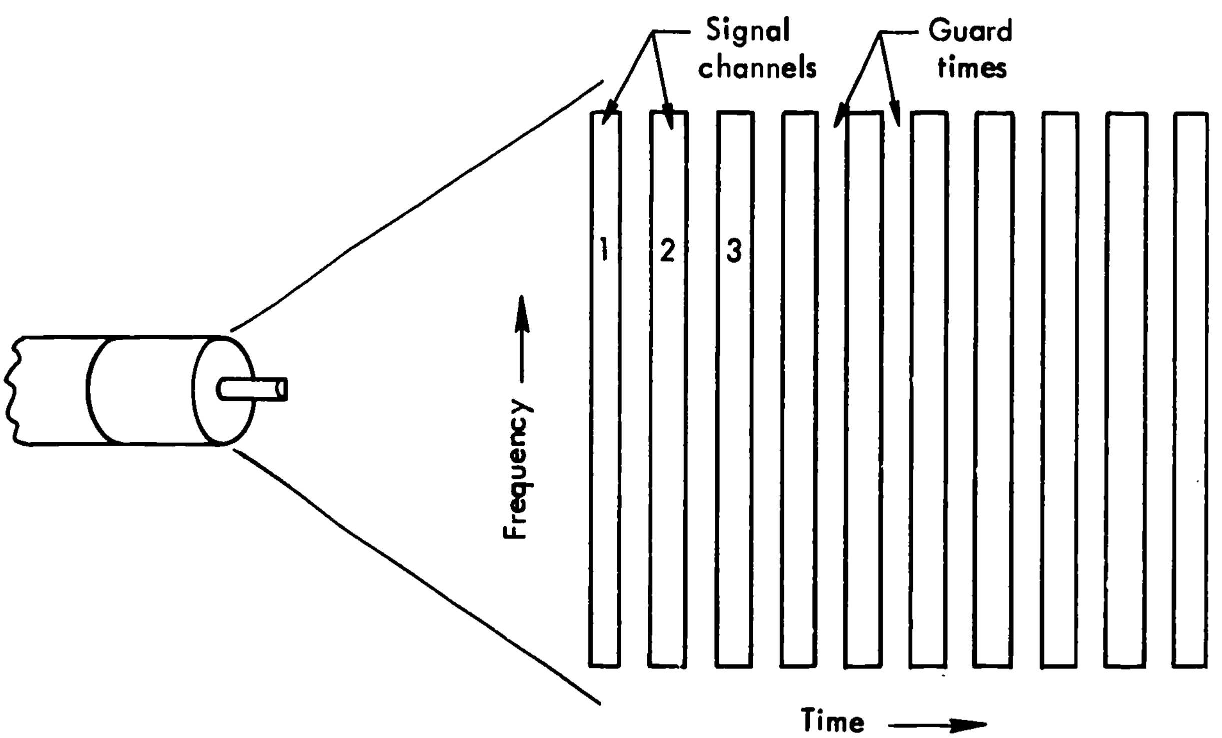
Multiplexing is accomplished by separating signals in frequency, time, or space. In frequency division multiplexing (FDM), a given bandwidth is divided into smaller frequency ranges as shown in Figure 2a. Frequency multiplexing is applied most naturally to continuous or analog signals such as voice and video. One-way cable television systems use FDM techniques to carry twelve or more video channels, each with a bandwidth of 6 megahertz (MHz),[1] downstream on a single cable. Time division multiplexing (TDM), as shown in Figure 2b, divides a channel into separate time slots for each signal; the time slots are then interleaved together. Computer data and other digital messages are most naturally handled in this manner, although TDM techniques are increasingly being applied to telephone voice transmission. Finally, signals can be physically separated in space (SDM): that is, sent over entirely different transmission lines.

These three multiplexing techniques can be combined within a single cable network. The most straightforward method is to divide

[1] A hertz is a unit of frequency, equal to one cycle per second.



(a) Frequency division multiplexing



(b) Time division multiplexing

Fig. 2—Frequency division and time division multiplexing

the usable cable bandwidth into separate frequency bands by FDM, with perhaps a different multiplexing scheme within each band. For example, Figure 3 schematically indicates how upstream digital data from subscribers can be time division multiplexed in a low frequency band, such as 5 to 30 MHz, while twelve or more downstream video channels are frequency multiplexed between 54 and 300 MHz. Diplexing filters would be used to separate the upstream and downstream signals. A second cable might have several different data (TDM), voice (FDM or TDM), and video (FDM) channels sandwiched together. Many such combinations can be used for two-way cable television services.

Bandwidth

For intracity cable communications, the transmission cost of a service will depend in large part on the amount of information transferred. Even coaxial cable has a finite usable range of frequencies that limit some of the more "blue sky" proposals for new communication services. With current amplifiers that range is approaching 300 megahertz. Some services, like simple opinion polling, demand only a single bit[1] -- yes or no -- response. Others, like remote shopping, may require that a few alphanumeric characters or several tens of bits pass upstream from subscriber to headend. Such data or message services, multiplexed by TDM techniques, require only about 100 hertz (Hz) per subscriber upstream. In contrast, a voice channel requires 3-4 kilohertz (KHz), and standard color video transmission uses 6 MHz. Thus color video origination by one subscriber might require more upstream bandwidth than returning digital data from 50,000 households.

Downstream voice, video, and data can be broadcast to all subscribers or individually addressed to one or many. Information retrieval, such as stock market quotations or reservation services, may involve a display of several lines of characters on the individual subscriber's screen. At six bits per character, and six characters per word, a line of 8 words would require about 300 bits, including

[1]A bit (binary digit) is the common unit of information.

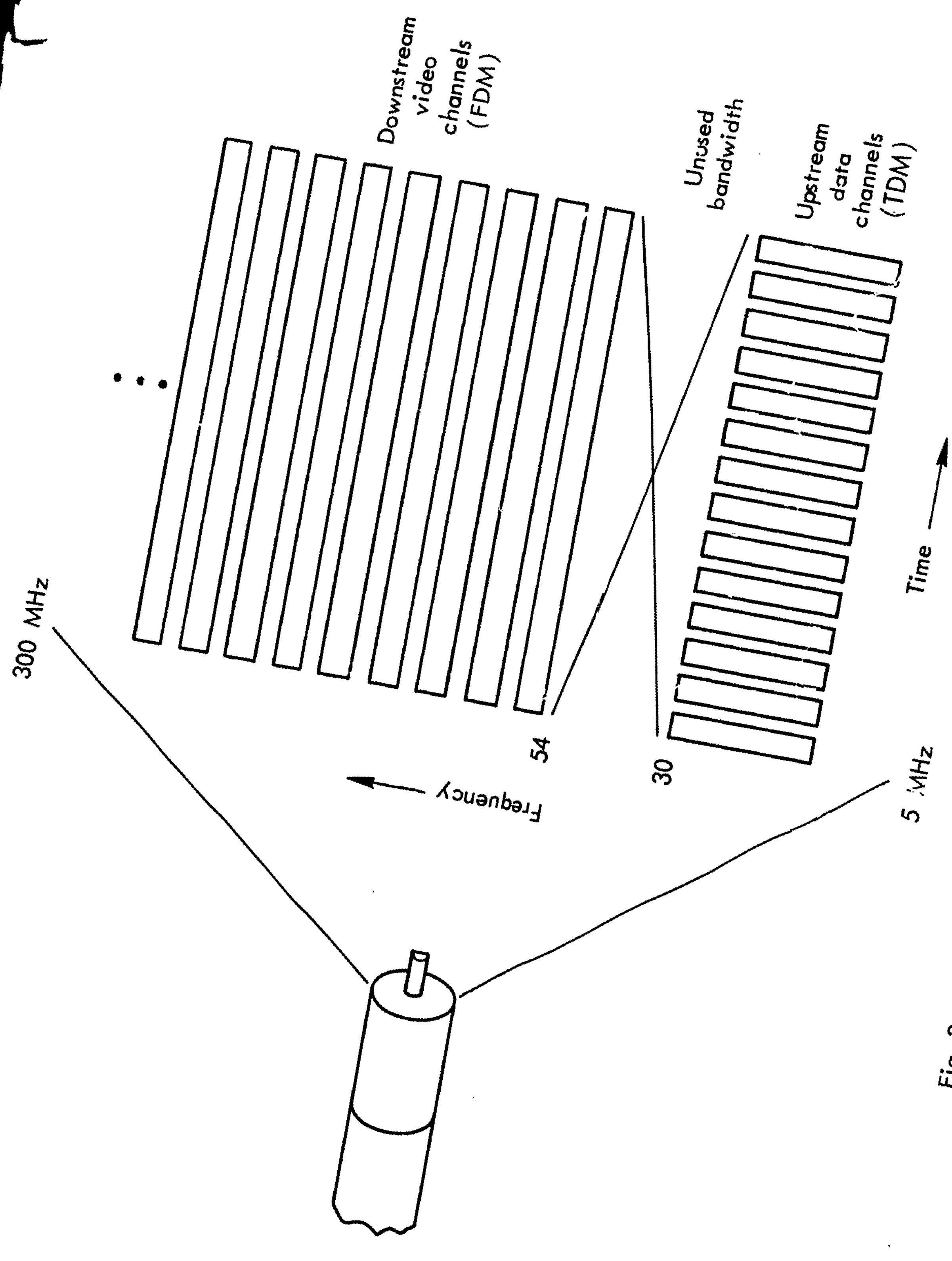


Fig. 3—Schematic for two-way transmission on a single cable

error checking and control bits. A standard 19-inch television screen can accommodate about 12 lines, or 3,600 bits in each frame for comfortable reading. A still picture on the television screen contains about 250,000 bits of information.

In this report the term "narrowband" is used to describe services requiring transmission bandwidths less than 3 KHz; "voiceband" for 3 to 4 KHz; "wideband" for 4 to 1,000 KHz; and "broadband" for bandwidths above one megahertz.

Terminal Equipment and Software

Two-way services require additional equipment at the system head-end and at each participating subscriber's location. Terminal equipment generally will be far more costly than the equipment installed for two-way transmission on the network. Some devices, such as home facsimile terminals for newspaper delivery, are not even into the product development stage. Others, such as single frame storage devices, are being developed in several places but are still relatively expensive. The cost of terminals is a basic item in determining the feasibility of two-way services.

Software ultimately is likely to be as critical as terminal hardware in determining the cost and feasibility of two-way subscriber services. Software in the context of cable communications includes not only the computer programming necessary to operate a two-way network, but also the computer application software, video programs, and other media material (such as pictures, audio recordings, and text) needed for each specific service. Every two-way service, from home shopping to interactive TV games to automated library reference, will require extensive software development. And for many services -- such as alarm monitoring -- the communications link will represent only a small fraction of total cost.

Technologists and managers alike often tend to underestimate the non-hardware costs of providing services made feasible by a new technology. In this respect, the development of cable communication services may be analogous to the development of computer time sharing services in the 1960s. At first, computer system designers consistently underestimated the difficulty and cost of creating system software for time sharing. Then, once time sharing systems were up and running, users found that applications software represented an increasing fraction of total computing costs. This is to be expected, since each new use of an existing computer configuration requires new applications programming but only a small increase (if any) in hardware cost. The ratio of non-hardware to hardware costs might in fact be taken as a measure of utilization or maturity of a computer system. Following a similar argument, one would expect the software costs of two-way cable communications services to predominate as use of the two-way network increases.

CATEGORIZING NEW CABLE SERVICES

Using the above parameters one can begin to group new cable services according to their implications for the network. Table 2 presents such a grouping -- not as a neatly defined taxonomy but as a means for discussing those services with common hardware features. Some rough, largely order-of-magnitude hardware costs[1] can be estimated for each group of services, based on quoted 1971 equipment prices and the author's knowledge of developments now underway. For an urban cable system with 5,000 or more participating subscribers (as is assumed here), additional hardware costs are dominated by the subscriber terminal equipment for all but one-way broadcast services.

One-Way Broadcast Services

The FCC's proposed rules for cable television would require that cable systems in the major markets have the capacity to carry at least twenty video channels downstream. Moreover, for each channel carrying off-the-air or imported television signals, cable systems would have to provide one channel for other uses.

[1] These are estimated costs to the cable system operator or user, which represent manufacturers' prices, although some are based on estimated manufacturing costs.

Table 2

CATEGORIES OF NEW CABLE COMMUNICATIONS SERVICES

Service Category	Downstream Signals	Upstream Signals	Equipment Requirements: Headend Equipment	Equipment Requirements: Subscriber Equipment
I. <u>One-way broadcast services</u>	6 MHz broadcast video channels (FDM)	None, except for local origination which may require one or more video channels from origination points to headend	Additional signal processing and multiplexing equipment: origination equipment	Converter or switch to receive > 12 channels
A. <u>Additional channels</u> TV entertainment programs instructional programs coverage of local events local program origination community bulletin board municipal services information (health, housing, welfare, etc.) local ombudsman				
fm radio foreign radio recorded music	200 KHz radio channels (FDM)			
B. <u>Subscription channels</u> movies entertainment programs instructional programs sports and special events			Signal scrambler or encoder	Unscrambler, decoder or special converter
II. <u>One-way addressed services</u> electronic mail delivery newspaper and periodical delivery selective video	Individually addressed wideband signals (FDM or TDM)	None	Information storage facilities: document scanner; address generator; communications controller	Address decoder and logic unit; video tape recorder, facsimile or other recording unit
III. <u>Narrowband subscriber response services</u>	Broadcast video (FDM), plus individually addressed narrowband polling signals (TDM) of 100 or fewer bits	Narrowband response digital data (TDM of 100 or fewer bits from individuals to headend	Central polling scanner, and communications controller (mini-computer): files, displays and other peripherals	Basic control unit (receiver, digital decoder, control logic, digital encoder and transmitter): buttons or keyboard, channel monitor
A. <u>Interactive television</u> entertainment programs instructional programs opinion polling remote shopping municipal services information				A. identification or authorization key
B. <u>Sensor monitoring</u> audience counting alarm monitoring meter reading cable system maintenance				B. channel sensor fire and intrusion sensors meter encoders amplifier and other component sensors

Table 2, continued

Service Category	Downstream Signals	Upstream Signals	Equipment Requirements: Headend Equipment	Equipment Requirements: Subscriber Equipment
C. Control of remote devices alarm sounding utility load control				C. switches and links to controlled devices
D. Subscription television			D. Signal encoder; billing mechanism	D. Decoder or special converter; authorization key
IV. Shared two-way channels	Same as III.	III, plus	III, plus equipment to recognize and queue requests, enable and disable subscriber equipment	III, plus
A. Voice response instructional programs entertainment programs community service information special interest group conversations local ombudsman		A. 3-4 KHz voiceband channel(s) (FDM)		A. Microphone, speaker and associated equipment
B. Video response instructional programs remote medical diagnosis neighborhood program origination		B. 4-6 MHz video channel(s) (FDM)		B. Camera and associated equipment
V. Subscriber initiated services catalog shopping stock quotations ticket and reservation services information from various directories and references computer time sharing computer assisted instruction checkbook balancing and other banking services dial-up video library business credit checks	III, plus individually addressed information (alphanumeric message or picture); bandwidth dependent on type of information, but usually voiceband or greater	III, with narrowband (but sometimes > 100 bit) response	III, plus source data bases (digital data, pictures, etc.) connected to central controller; billing mechanism	III, plus extended keyboard, local storage (buffer or refresh) and output display device (character generator, strip printer, frame freezing device, video tape recorder or facsimile)
VI. Point-to-point services	Individually addressed, variable bandwidths for data, voice and video transmission; primarily FDM with TDM for data	Individually addressed, variable bandwidths for data, voice and video transmission: primarily FDM with TDM for data		
A. Message-switched services message transmission business transactions computer input/output			A. Store-and-forward processor	A. III, plus buffer storage and keyboard printer
B. Point-to-point circuits high speed data exchange facsimile fingerprint or photograph identification teleconferencing closed circuit TV videophone			B. Equipment to set up private or multi-party channels	B. Data, voice, and video terminals as required; special frequency converters and associated logic for channel selection

These rules, if enacted, plus the cable operators' own interest in attracting new subscribers, will encourage the development of additional one-way broadcast services. As listed in Table 2, the services include commercially syndicated program packages for cable (including the automated time, weather, news, and stock market ticker now widely used by cable systems), local origination, instruction, and public service programming.

The extra hardware for additional one-way broadcast services includes equipment for local origination and signal processing, a converter for each subscriber so that he can receive more than twelve channels, or a second cable for downstream transmission plus a switch at each receiver. The added cost of this equipment would be $30 to $60 per subscriber, assuming no elaborate origination facilities.[1]

The cost of obtaining program materials and the revenues anticipated from them would then be expected to determine what programming was offered on the additional channels. Issues of local origination and community service programming have been widely discussed elsewhere.[2] These one-way services -- though hardly new to cable television -- are the ones most likely to be expanded in the near term.

Limited access or subscription channels also can be made available on a one-way broadcast basis by encoding signals at the headend and transmitting at frequencies that regular subscribers cannot receive. Special converters and decoding units would then be given to participating subscribers. Such devices are now being marketed to cable operators at an added cost, according to their promoters, of $25 to $70 per subscriber. Again, the feasibility of subscription television will be determined by the economics of programming rather than of hardware.

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[1] W. S. Comanor and B. M. Mitchell, "Cable Television and the Impact of Regulation," Bell Journal of Economics and Management, Vol. 2, No. 1, Spring 1971; and W. S. Baer and R. E. Park, "Preliminary Financial Projections for a Cable Television System in Dayton, Ohio," The Rand Corporation, unpublished manuscript.

[2] N. E. Feldman, Cable Television: Opportunities and Problems in Local Program Initiation; also, D. Anderson, "Experienced Perspective on the Origination 'Bug'."

One-Way Addressed Services

Much past enthusiasm for the development of broadband cable networks has come from the prospect of electronic delivery of mail, newspapers, magazines, and other documents.[1] In a one-way system, the subscriber would receive items addressed to him or those matching his pre-selected interest profile. In a two-way system (described below) he could request specific documents. For one-way addressed services the document usually would not be displayed directly on his television receiver, but would be printed out on a hard-copy device or stored on a video tape recorder (or equivalent) for future playback. Thus, newspapers and other large volumes of information could be transmitted at night when cable channels were otherwise unoccupied. The subscriber would need a control unit to turn his recording device on and off at the headend's command. This also implies some sort of address generator and communications controller at the headend.

Equipment is available to transmit and receive documents at high speed. The chief problems are cost and ease of use. Videotape-to-videotape transmission on a 6 MHz channel can proceed at a rate of 30 frames of text each second. Using 100 words per frame, an average 40,000 word newspaper[2] could be recorded in about 13 seconds. However, videotape recorders with adequate frame-by-frame playback capability now cost upward of $1,000, to which the address decoder and logic unit to control the recorder might add another $100. The development of cartridge videotape recorders should make these machines simpler and cheaper, but a cost reduction of a factor of two by 1976 seems the most optimistic estimate. Moreover, frame-by-frame viewing of documents is not satisfactory for many users. In his recent book The Information Machines, Ben Bagdikian comments on electronic newspaper delivery:

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[1]The Future of Broadband Communications; also, Addressed Cable Delivery, The IIA Response to FCC Docket 18397, Part V, Washington, D.C., Information Industries Association, December 1969.

[2]Ben A. Bagdikian, The Information Machines: Their Impact on Men and the Media, New York, Harper & Row, 1971, p. 102ff.

> The total transmission of "newspapers" in video form, without a document, is unlikely. The printed word will continue to have useful characteristics compared with sound or motion pictures or texts displayed on a screen.
>
> What is more likely is an acceleration of present trends of a gradual division of labor between audio and video presentation of some kinds of information, and printed display of others. Much of what is in newspapers -- stock-market quotations, movie listings, headlines -- would be satisfactory viewed on a screen only long enough for a reader to decide if further examination is desired. Other newspaper content will continue to be desirable in print -- longer articles, analyses with statistics or other information requiring the ability to reread or to compare items separated in space, and items for retention in personal records.[1]

The same desirable features of print apply in general to books, periodicals, and other documents of more than a page or two, as many users of microfilm have discovered.

Thus document delivery services probably would require some sort of hard copy recording. A polaroid camera would be cheap and useful for some hard copy applications but not for delivery of multi-page documents. High speed facsimile equipment such as the Xerox LDX can scan and print text at about 3,500 words per minute over a 240 KHz channel, while high speed printers operate at 6,000 words per minute. But this equipment, produced for special industrial and military markets, is very expensive today. Development has only begun on high speed units that would sell for less than $1,500. Moreover, per-page operating costs for paper and ink alone would be high, and the amount of paper needed in the home might be prohibitive. To quote Bagdikian again:

> It is not likely that any future home facsimile will produce newspapers like those now delivered by hand. The average number of pages for daily papers in the country is 53 on weekdays and 178 on Sundays. Larger newspapers have more pages than that. Each of these pages has 2.1 square feet of printed area, which would require a home reproducer to turn out over 100 square feet of printed surface every weekday and 374 square feet on Sundays.

[1] Ibid., p. xxxiii.

> The compact, preprinted paper delivered to the home will continue to be attractive for some time, for convenience. It will be even more attractive on the basis of cost. Newspapers produce one page per customer for about one-third to one-half a cent. Not even the optimists in home facsimile envision duplication of such low costs in the foreseeable future.[1]

Electronic delivery of first-class mail[2] might be justified by increased speed rather than lower cost.[3] Some mail presumably could be delivered up to 24 hours earlier by cable than by carrier -- a possibly important factor in business transactions. It should be noted, however, that intercity electronic mail transmission via microwave or satellite offers greater time saving possibilities than intracity transmission via cable networks. Electronic mail delivery also brings up the question of privacy, which is discussed in Section VI.

In summary, although a business market may exist today for hard copy, addressed document delivery by cable, the cost seems too high for home subscribers over the next five years. Document recording on videotape or other soft-copy device does not appear to be an important service in itself, but it might become attractive if videotape recorders are purchased for other reasons (such as recording of television programs for future playback). Only a small percentage of cable subscribers may be expected to have videotape recorders in the next five years.

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[1] Ibid., p. xxxiv.

[2] W. B. Gross, "Distribution of Electronic Mail Over the Broadband Party-Line Communications Network," Proceedings of the IEEE, Vol. 58, No. 7, July 1970.

[3] The cost tradeoff between electronic and letter carrier mail delivery does not appear bright for cable, particularly if letter carriers must still deliver periodicals, documents, and special correspondence. Even if the direct cost tradeoff favored electronic delivery, however, one should also take into account the societal benefits from our present system of letter carriers. Some of these can be quantified, such as the provision of employment to people who might otherwise receive welfare payments; others cannot, such as the sense of community that letter carriers bring to a neighborhood. But it is apparent that the U.S. letter carrier service today does not exist entirely by dint of its cost-effectiveness.

Narrowband Subscriber Response Services[1]

Two-way services requiring small quantities of return data from subscribers are evidently what the FCC has in mind initially in its proposed rules for cable. For these services a scanner at a central location[2] would ask each subscriber in turn to respond to one or several queries. If the subscriber (or monitoring equipment installed at the subscriber's location) has a response, that information is sent in digital form upstream from his terminal to the central point where it is recorded or processed. The computer might make queries something like the following:

"Is the television receiver turned on and, if so, to what channel?"

"Do you have an answer to the multiple choice question just asked on the morning reading program?"

"Who should win first prize on tonight's talent show?"

"Do you agree with Councilman Smith on that issue?"

"Is there a fire (intrusion, other emergency) at this location?"

"What is the gas meter reading?"

Each of these queries can be answered by pushing a button or by automatically sending a few digits of information to the central location. They require, therefore, relatively low information or narrowband responses. The system also could be capable of turning switches on or off remotely at the subscriber's location. This would permit the sounding of a fire alarm in the home (as well as sending an alarm to the nearest fire station), remote on-off switching of a special channel (for example, medical information for physicians), or remote on-off switching of appliances.

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[1]See also H. J. Schlafly, The Real World of Technological Evolution in Broadband Communications, a report prepared for the Sloan Commission on Cable Communications, September 1970, distributed by TelePrompTer Corporation, New York City, pp. 33-35. The definition and description of subscriber response services in this report is similar to Schlafly's.

[2]Here assumed to be at the headend, but it could be located elsewhere in the system.

Polled, narrowband response services require a central scanner and communications controller (probably a minicomputer), plus memory, files, and displays for the return data (Figure 4). The computer selects the addresses to be polled and the functions to be queried according to its programmed instructions. Addresses and functions can be different for each polling cycle, but the queries and responses remain under system control. Downstream polling signals must be modulated, brought to the headend transmitter, and frequency multiplexed with the downstream video channels for delivery on the cable transmission system. Upstream responses would be demodulated, collected by the computer, and processed. They could be printed out or displayed in real time (for example, responses to opinion polls), transmitted to other locations (such as alarms sent to a security central office), or recorded for future use (as with meter readings).

The basic subscriber terminal would include a wideband receiver and demodulator tuned to accept downstream polling signals, and a decoder to compare addresses received with its own address. If the addresses match, the subsequent message is sent on to the control logic unit; otherwise the message is ignored. Responses from the subscriber's push-buttons or keyboard, or from other devices, are assembled by the logic unit, encoded in digital form, and transmitted upstream at the appropriate frequency and sequence. This type of narrowband response subscriber terminal is estimated to cost upward of $300 at the present time, but the cost should drop to $100 to $250 in production quantities of tens of thousands.

Shared Voice and Video Channels

In the group of narrowband subscriber response services described above, a subscriber can transmit only data upstream to the headend. This may be a significant limitation for some educational programming, medical diagnosis in the home, or community information services where voice and even video feedback could be important. Voice response from off-campus locations has been used successfully in Stanford's televised

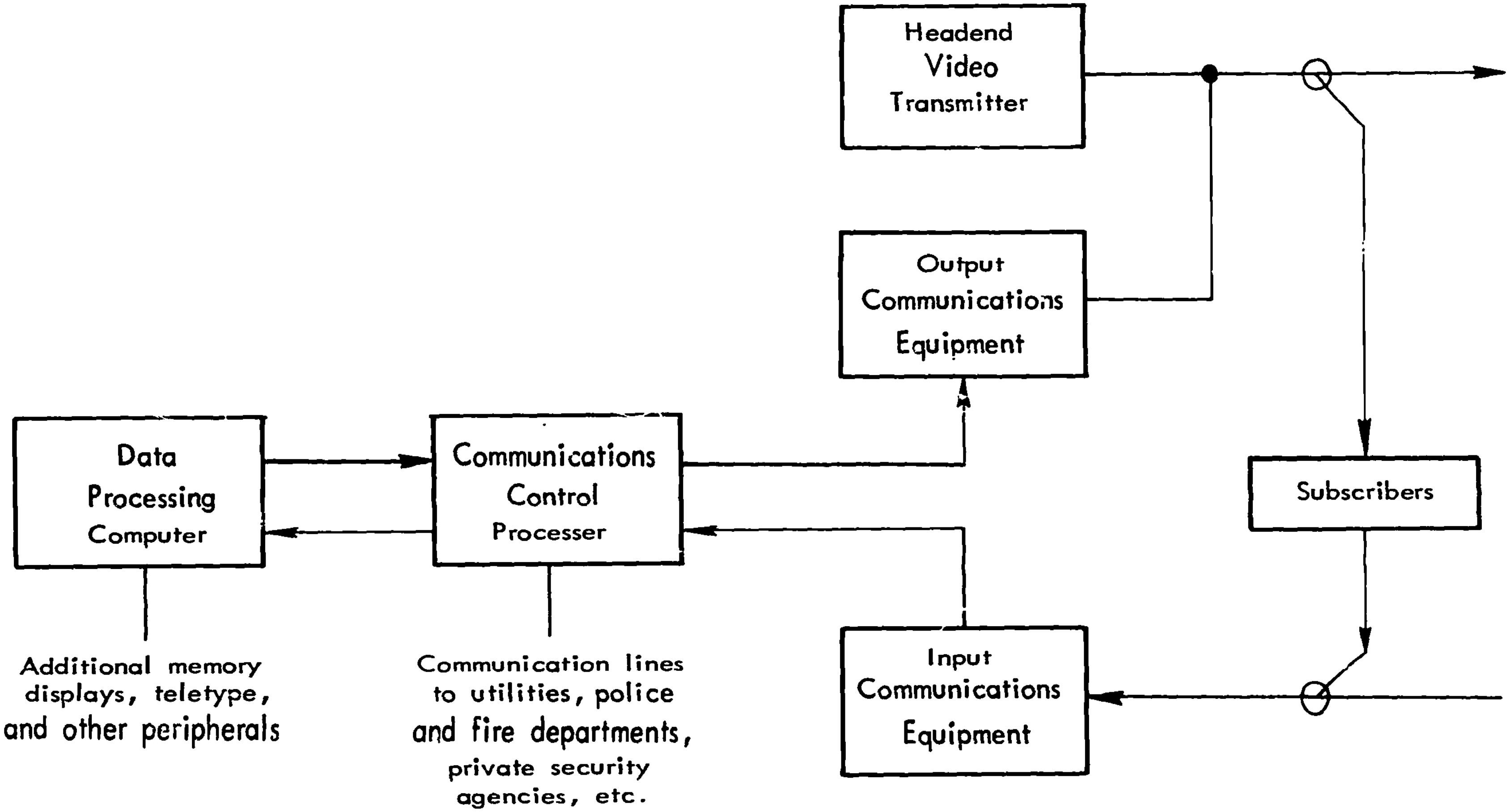

Fig. 4—Central computer facility for subscriber response system. This schematic assumes a separate return transmission line, but a single cable could be used for transmission in both directions.

engineering extension curriculum[1] and is being included in other university microwave systems for instructional television.

One obvious solution would be to use the telephone for voice response. A student watching a vocational education program, for example, could simply call up and ask questions of the instructor at a certain time. Appropriate call handling devices could be set up for queueing and retransmitting the viewer's voice onto the downstream video program, as is now done on radio "talk shows."

Yet a telephone return link can be inconvenient. The viewer must have a telephone close to his television receiver. He must dial the correct number and wait until a connection is established -- usually a matter of 20-40 seconds. Then, if his call is not first in line, he must hold the telephone receiver until he can talk with the instructor. The inconvenience could be minimized by using a telephone card dialer and speakerphone, but at considerable extra cost.

The simplest cable system approach to voice feedback would be to have one or more shared 4 KHz channels (FDM) available for upstream voice response in addition to the channels for subscriber return data. A student would use his digital response unit to signal the headend that he wanted to talk to the instructor. When his turn came, he would be notified (by a light or audible signal) and his microphone-speaker unit would be turned on by headend command. Following his conversation, the channel would be freed for another subscriber's use. The same procedure could be used for shared video response using a 6 MHz upstream channel.

Cable voice channels should have advantages of connection speed and convenience compared with return telephone circuits. Moreover, the direct link with the cable digital response unit could easily permit recovery of the caller's past responses. Again using vocational instruction as an example, the instructor could have the

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[1] J. M. Pettit and D. J. Grace, "The Stanford Instructional Television Network," IEEE Spectrum, Vol. 7, May 1970, pp. 73-80.

caller's keyed-in answers to that day's questions displayed for him while they were talking. This would be much more difficult to coordinate with a telephone response system.

The cost for the subscriber's microphone, speaker, modulator, frequency converter, enable/disable switch, and associated logic would at present be $50-100 over and above that for the digital response unit. The cost would be expected to drop by a factor of two if several thousand units were purchased. This still would be more expensive than a simple extension telephone but on the same order as a telephone with card dialer and speaker. The headend facilities could range from a few thousand dollars upward, depending on what kinds of queueing, caller information, and data retrieval capability were required. No particularly difficult system design or computer software problems should be encountered in adding shared channels alone.

Equipment to use shared video channels would be more expensive. A cheap black-and-white camera, modulator, and associated equipment would today cost about $1,500 at each location.

Subscriber Initiated Services

Letting the cable subscriber initiate requests for service opens up a vastly richer range of services than is possible with system polling alone. No longer restricted to answering questions or responding to items presented on his television screen, the subscriber could request information or entertainment at his convenience. The telephone network offers this capability today with recorded voice and data responses. By dialing the appropriate number, a telephone subscriber can receive time or weather information, hear various recorded messages, or be connected to a computer time sharing service. A two-way cable network could make wideband data, still picture, and recorded video responses available as well.

With today's technology cable subscribers could make requests using a telephone-like push button device or a full alphanumeric keyboard. A full list of services available and their access codes could be sent to each subscriber or displayed on his television screen. The subscriber's request would be processed by the headend computer and referred to the appropriate information source. When the requested information was located, it would be sent back to the headend, tagged with the subscriber's address, and then transmitted downstream over the cable network to him. The headend computer would function, in effect, as a switch connecting the subscriber to the information source.

An information retrieval system, however, would require a larger computer and more storage capacity at the headend than is needed for subscriber response services. Moreover, developing the computer software for such a system is far from easy. In the past, many millions of dollars have been spent each time a new multiprocessing system has been built. And there are, at present, no user-controlled systems that can serve several thousand terminals simultaneously, as would be contemplated for cable television subscribers.

Assuming that the necessary system software were available, requests for information such as stock prices, bus schedules, locations of health care centers, and the like would generally require answers of 500 characters or less. A small strip printer, probably available for less than $100, would provide a simple home output device. Still, it is more likely that the response would be displayed directly on the subscriber's television receiver.[1] This can be done either by adding an alphanumeric generator to the subscriber data terminal, or by transmitting a single frame downstream for recording and display as a still picture on the screen. The latter technique, known as "frame grabbing," "frame snatching," or "frame stopping," is by far the more powerful since it permits displays of pictures, charts, and drawings as well as alphanumeric characters.

Functionally, a frame stopping device contains the same sort of receiver and address decoder as a subscriber data terminal, plus

[1] Other graphic display terminals are in development and eventually may be available at low cost. One example is the plasma display terminal developed at the University of Illinois for computer aided instruction. See D. Alpert and D. L. Bitzer, "Advances in Computer-based Education, Science, March 20, 1971, pp. 1582-1590.

electronic or magnetic storage to record a single frame, and a control unit for recording and displaying the frame on a standard television receiver. None of this is technically difficult, but frame storage still is relatively expensive. The first frame stopping device to be publicly demonstrated was recently shown by the MITRE Corporation in Reston, Virginia.[1] It was just developed as a terminal for computer aided instruction[2] and employs an inexpensive helical scan videotape recorder for frame storage. A frame addressed to the subscriber is recorded at his terminal. It then is continuously replayed from the videotape recorder onto his television receiver until a new frame is ordered.

Similar frame stopping terminals might cost about $1,500 commercially at the present time, although MITRE expects the development of low-cost videotape recorders to dramatically reduce this figure in two to five years. The maintainability of large numbers of inexpensive videotape recorders in homes is not at all clear, however, and other frame storage devices, such as electronic storage tubes, may be available at a cost below $500 by 1976. On the other hand, a videotape recorder could also be used for dial-up document delivery in which the subscriber selects the material to be transmitted downstream and recorded for subsequent playback.

In the MITRE system, one individually addressed frame can be transmitted every 1/60th of a second on a single video channel. Thus, if the subscriber retains a frame for 10 seconds on the average, one 6 MHz downstream channel could serve 600 subscribers simultaneously. In contrast, a dial-up video library service, in which a subscriber could call up films or television tapes on demand, would require a separate

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[1] J. Volk, The Reston, Virginia Test of The MITRE Corporation's Interactive Television System, The MITRE Corporation, MTP-352, May 1971.

[2] K. J. Stetten, The Technology of Small, Local Facilities for Instructional Use, The MITRE Corporation, MTP-347, January 1971; K. J. Stetten, R. P. Morton, and R. P. Mayer, The Design and Testing of a Cost Effective Computer System for CAI/CMI Application, The MITRE Corporation, M69-39, April 1970.

6 MHz downstream channel for each request. This may be more practical for schools, hotels, and other closed circuit applications than for urban cable systems with many thousands of subscribers.[1]

Point-to-Point Services

The services described above link cable subscribers with the system headend or other central facility. A more generalized capability would allow one subscriber to communicate with another -- as the telephone network does by physically connecting subscriber lines at switching centers. The same result can be accomplished in a tree-like cable network using message switching or frequency conversion techniques.

A cable system can be readily adapted for message switching, or store-and-forward transmission of printed messages, business transactions, and computer data. In this system the caller requests use of an upstream message channel from the headend. When a channel is available, the caller sends the recipient's address and message upstream to a processor at the headend hub. The processor stores the message until a proper downstream channel is available; the addressed message is then sent downstream to the receiver's terminal. With message switching the sender and receiver need not be linked in real time. The hub processor serves as a buffer between them and, as a result, can load message channels with greater efficiency. These channels would be different from those used for system polled, narrowband response services, since they would permit larger amounts of information to be transmitted to and from subscribers. The subscriber terminal would be functionally similar to that for polled, narrowband responses, with the addition of some buffer memory and a keyboard

[1]Dial-up video playback systems have been successfully tested in public schools in Ontario, Canada and West Hartford, Connecticut. A dial-up system based on Ameco DISCADE equipment is being installed in the Disney World Hotel near Orlando, Florida. A hotel guest will be able to select feature-length movies as well as television broadcasts on the television receiver in his room. A somewhat similar system also is being tested by Computer Television, Inc. in a Newark, New Jersey hotel.

printer. Using an inexpensive teleptype printer, the terminal might cost roughly $800 to $1,000.

Point-to-point voice, video, and some data services require direct communications links between two or more points. This is most easily handled on a cable network by assigning special frequencies for these services.[1] Separate frequencies would be needed for upstream and downstream signals. The caller's signals would go upstream to the headend, be converted to the corresponding downstream frequency, and then be transmitted downstream to the receiver. Alternatively, separate cables could be used for upstream and downstream signals. Some users might be given exclusive use of a frequency band -- much like a closed circuit television system. For example, a police department might link all municipal precinct stations for facsimile and two-way video transmission. Other users, such as the public school system, might need several video channels during the day but not at night. These channels could then be made available to different subscribers for wideband data exchange. Still other users might lease a channel only occasionally. Each point-to-point subscriber would have a special frequency converter, possibly controlled from the headend, for access to his assigned channels. The cost of his terminal would obviously depend on his specific use. A medium quality video terminal with monochrome camera, modulators, and fixed frequency converters, for example, might cost $2,500 to $3,000, exclusive of the television receiver. A studio quality, color video terminal would cost upward of $10,000.

The logical extension of point-to-point services on cable would be dial-up 6 MHz videophone service to and from any subscriber on the system. Bandwidth limitations, however, make this an unlikely service for a tree-like cable network. Dial-up videophone service among several thousand subscribers seems more appropriate for a circuit switched network than a party-line cable system.

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[1] Time division multiplexing could, of course, be used for data transmission within an assigned frequency band.

PROJECTING THE NEAR-TERM DEVELOPMENT OF NEW CABLE SERVICES

To accommodate all of the above services, then, a cable subscriber's terminal might include a large color television receiver, a frame-stopping device for alphanumeric character and still picture viewing, a video recorder with enough storage capacity for feature films or several volumes of text, a facsimile receiver, a printer for messages and data, a full keyboard for message entry, a camera and microphone for video and voice communications, links to sensors and appliances, and a sophisticated control unit. This is clearly a vision for the future. Although each of these components already is technically feasible, most are simply too expensive to see wide implementation on cable television systems in the next five or even ten years.

A comparison of estimated terminal costs for the several groups of new services is shown in Figure 5 for the years 1971 and 1976. (Cost estimates are over and above those for standard television receivers, which are shown separately.) This figure should be approached with several caveats. First, the terminal cost is only part of the total cost to provide a new service, although it will likely be the dominant hardware cost for large systems. Second, since no real market has previously existed for most of these services, only prototype terminals have as yet been designed and built for them. Thus, although the cost of a teletype-like data terminal or a closed circuit video terminal can be estimated relatively easily, estimating the manufactured cost of a frame-stopping or home facsimile terminal presents much greater uncertainty. The 1976 estimates assume that terminals are manufactured in quantities between 5,000 and 50,000 -- giving both economies of scale and learning-curve cost improvements. Finally, the feasibility of a new service depends on its value relative to its cost, not on its cost alone. A high cost service, such as closed circuit, two-way video, will be feasible if subscribers are willing to pay high enough charges for bandwidth and terminals. Cable system operators, to the extent they rationally seek to maximize profits, must take this view in introducing new services.

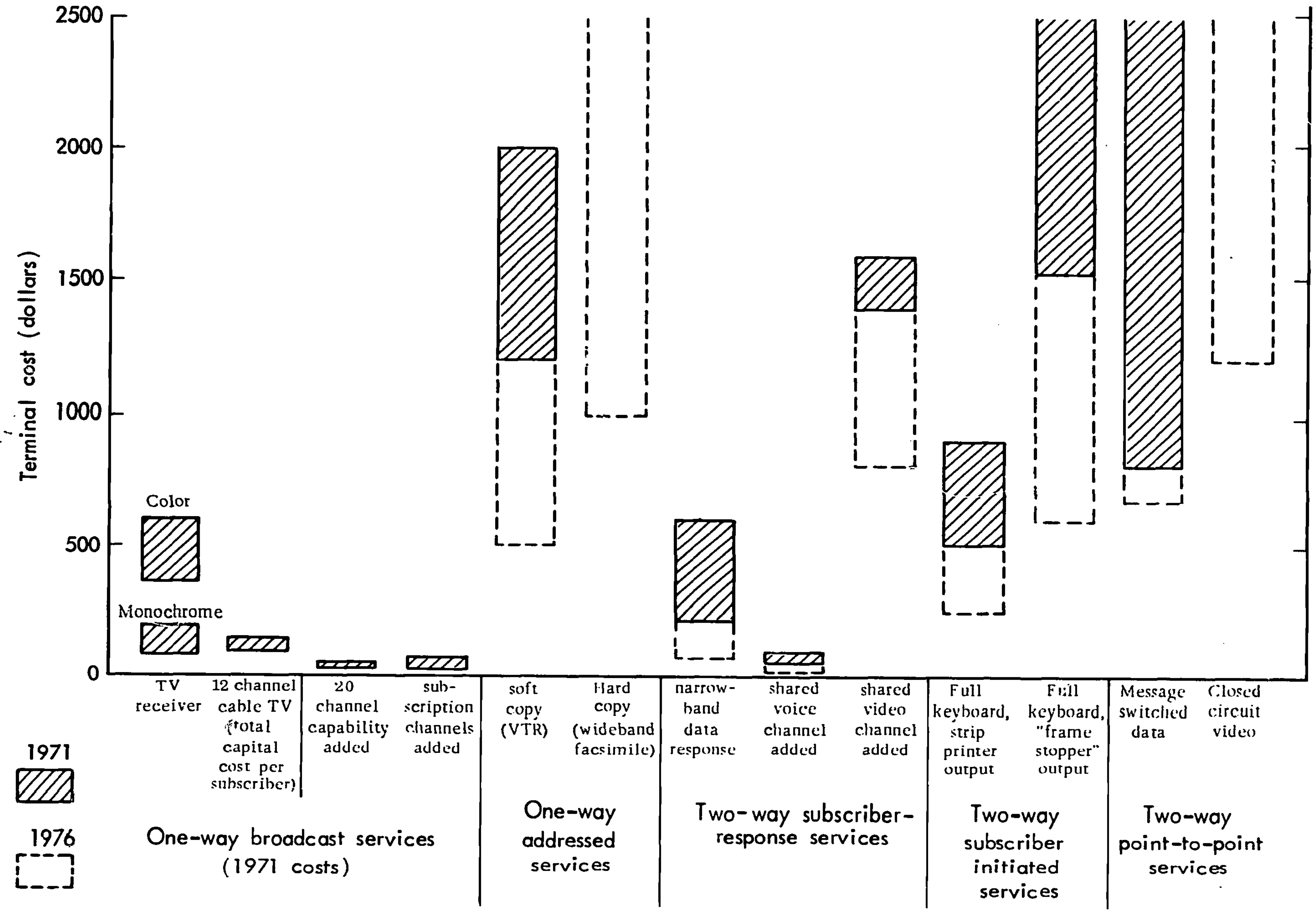

Fig.5 — Subscriber terminal costs for new cable communications services

Nevertheless, Figure 5 does present some useful comparisons. As a yardstick, the typical capital cost for a twelve channel cable system, determined from published data from a number of cable system operators, is $90 to $150 per subscriber.[1] The capital cost for twenty or more channels entails another $30 to $60, and encoding for subscription channels adds a like amount. On the basis of the added capital investment required, therefore, these services appear commercially feasible for home subscribers whenever attractive programming is available. At the other extreme, the high hardware costs for two-way, point-to-point and one-way, addressed services make their use by residential subscribers highly unlikely in this decade.

Two-way, point-to-point services for business and institutional subscribers may well be feasible, however, particularly since the cable operator does not have to supply programming or other software for these services. Intracity business data transmission would be a prime example, both for wideband computer-to-computer data transfer and for narrowband transactions such as local credit card verification. But the switched telephone network (with increased use of voice response from a central computer) will continue to provide stiff competition for cable for most narrowband business transactions. Cable networks in the major cities would also be attractive for two-way, local distribution of intercity data communications carried by the newly authorized special common carriers.

Other two-way services also must be oriented toward business and institutional markets until the cost of providing these services is below the price that home subscribers will pay for them. If one assumes that $15 to $20 per month represents some upper limits on the price most consumers would pay for most two-way services listed in Table 2, then the capital cost to provide them must be less than $600 per terminal -- an argument which is developed further in Section IV. This itself would serve to separate analysis of subscriber initiated

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[1] The range is due more to differences in subscriber penetration than in the cost to build a twelve channel system.

and system polled, subscriber response services. Given this assumption and the terminal cost estimates of Figure 5, subscriber initiated services will be too expensive to make a major impact in the home before 1976 and perhaps before the end of the decade. Moreover, the cost of developing system software for a variety of subscriber initiated services represents a formidable barrier to their early implementation.

Subscriber initiated services using cable television networks may be developed successfully for other applications -- such as computer-aided instruction in the schools[1] -- and may be important to residential subscribers in the 1980s. But for near-term interactive cable communications in the home, one should now examine the possibilities for system polled, narrowband response services.

[1] K. J. Stetten, The Technology of Small, Local Facilities for Instructional Use.

III. NARROWBAND SUBSCRIBER RESPONSE SERVICES

This section outlines a number of possible two-way subscriber sources that fall under the heading of "system polled, narrowband subscriber response" services, as described in Section II. All such services are initiated and controlled from the system headend, with each subscriber polled in turn by a central computer. Subscriber responses are limited to one or at most a few data characters (perhaps 50 bits). Responses are transmitted upstream to the headend in definite sequence, using time division multiplexing. This group does not include information retrieval, computer time sharing, and other subscriber initated services that would represent a significantly greater step in both capability and cost.

AUDIENCE COUNTING

Television networks and advertisers pay large sums for television rating surveys that report viewer program preferences. These surveys are now done on a statistical basis with relatively small samples -- the "Nielsen ratings," for example, are formulated from a national sample of about 1,200 households. The accuracy of these television ratings has been questioned both in Congress[1] and by the advertisers who pay for them.[2]

A two-way subscriber response system would provide a low-cost way of counting audiences from 100 percent of participating households. An on-off and channel sensor would be the only subscriber equipment needed beyond the basic response unit described in Section II. Viewer distribution among channels could be determined several times a minute, so that fall-off of viewer interest during a program could be recorded and correlated with program material. For example, the number of

[1]"Broadcast Ratings," Report of the House Subcommittee of the Committee on Interstate and Foreign Commerce, 88th Congress, First Session, 1963.

[2]For example, see "TVB Still Unhappy with Audience Surveys," Broadcasting, June 28, 1971, pp. 41-42; and "Hard Nudges for ARB and Nielsen," Broadcasting, May 17, 1971, p. 30.

receivers switching channels or turned off during a commercial could be counted. Correlations also could be made between program viewing and demographic data such as occupation, age, and family size.

The commercial importance of audience counting over cable television should not be overstressed, however. First, the population of cable television subscribers who additionally receive two-way services would be self-selected and probably quite different from the total viewing audience. Thus, the results from audience counting among two-way subscribers would be expected to differ from results of Neilsen-type surveys. The latter might be more useful to mass-market advertisers than the former. Second, the recording device at the headend could count only how many receivers were on and tuned to each channel. It could not tell whether the whole family was watching or only a three-year-old child.

One expects that the television networks and national advertisers would be extremely interested in the first city-wide use of audience counting on a two-way cable system. They would compare its results carefully to those of previous surveys. But once these initial results were in, large-scale audience counting in other cable systems would be less important for national surveys and ratings.

Audience counting would have particular significance for local spot advertising, and for non-commercial programming where it may be important to know the audience size for specific instructional, community, or public service programs. Cable, after all, is meant to serve smaller, specialized audiences, and some programs may be considered successful if they attract one-half of 1 percent of total subscribers. Measuring an audience of 50 in a cable system of 10,000 subscribers with reasonable confidence would be inordinately expensive using present sampling techniques. Yet a cable system with subscriber response capability could routinely count such small audiences accurately at low marginal cost.

DIRECT VIEWER RESPONSE

A few buttons or a Touchtone-like keyboard connected to the subscriber's response unit would allow direct viewer interaction with televised programming. An enormous number of applications -- ranging from trivial to profound in impact -- would thus be opened up for new public and private services.

Remote Shopping

Considerable interest has been expressed in remote shopping, for example, where a cable television subscriber could order a product at the time it is advertised. The transaction would be recorded and sent directly to the local advertiser, or else billing could be handled by the cable operator. Local auctions could be conducted in the same manner. Presumably, each response unit would have a key-actuated order button or special code so that unauthorized persons could not order merchandise. The added cost of this feature would be two or three dollars at most.

Remote shopping would be attractive to advertisers eager to stimulate impulse buying. Special "shopping channels" might be leased to local merchants (at rates of a few dollars per minute in a large capacity system) to display their wares. The choice of items displayed would be the advertiser's, since a two-way, narrowband response system would not enable viewers to browse through catalogs at their choice and convenience.[1]

Viewers might value the convenience of shopping via interactive television, but it is fair to ask why more consumers do not order goods by telephone today. Many large department stores advertise special items on television and ask viewers to phone in their orders immediately. Yet this does not represent an important factor in total retail sales. Grocery ordering by telephone has fallen precipitously in the past

[1]Independent of the question of terminal cost for subscriber initiated services, building a multiple user, fast access information source containing (say) the Sears, Roebuck catalog would appear to be a multi-million dollar project today.

generation as supermarkets have taken over food retailing. And one recent attempt at large-scale grocery distribution with telephone ordering and computerized order processing quickly ended in bankruptcy.[1]

Remote ordering may be more convenient by pressing a few buttons on a cable television response unit than by placing a telephone call. Yet whether by cable or telephone, remote ordering represents only part of the overall shopping process. Convenience may in many cases be less important than the ability to compare objects directly and inspect the actual item purchased -- not to mention the subjective satisfactions people often get from personal contacts in stores. Analyzing these factors is the province of consumer motivation research. For this report, the point is that the value of remote shopping via cable television -- like that of other two-way cable services -- is as yet unproved in the marketplace.

Interactive Programming

A variety of television entertainment programs could be enhanced by direct viewer response. These might include programs similar to the "National Drivers' Test" in which audience responses to situations presented on the screen were immediately totaled and discussed; quiz shows or contests where audience judgments could be compared with those of a preselected panel; or dramatic improvisations that would be responsive to audience preferences. Viewers could respond to issues presented in debate form as on "The Advocates" program shown over public television stations.

The extension from response to an "Advocates" debate to participation in actual political issues is an obvious one. Local City Council or Board of Education meetings could be televised and citizens invited to respond at certain times to issues under consideration. This "electronic referendum" could bring the concept of the town

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[1]"'Shopping Method of 21st Century' Collapses," The Los Angeles Times, June 11, 1971. According to its promoter, the Telemart enterprise failed because of technical problems. The system was unable to handle the volume of orders received.

meeting into modern urban life. There are, needless to say, potential dangers as well as benefits from direct response on political issues. The likelihood of quick, emotional responses to complex issues would be the principal danger. Would a direct television poll on prison reform immediately following reports of the killings at Attica, New York have been useful, for example? Determining the age or voter eligibility of those responding also would pose a problem. These and other questions bear close watching in any test of direct viewer participation in the political process.

Market Surveys

Commercial opinion polls and market surveys also could be conducted by direct viewer response to yes-no or multiple choice questions keyed to advertisements or programs. Such surveys might give more accurate measurements of the specific impact of particular program segments than current techniques. They also would have advantages of speed and low cost in data gathering, and accurate sample preselection from demographic data or from the cable operator's own subscriber records.

Instructional Television with Feedback

Direct response by students could have significant impact on instructional television.[1] Electronic systems to record student responses in the classroom are being sold by several manufacturers. A typical system provides each student with a four-button response panel connected by wire to a central console. During a classroom presentation the instructor can receive immediate feedback from multiple choice or yes-no questions. The percentage of the class responding with each of the four choices is displayed at the console, and individual student responses are recorded for immediate use or later evaluation. These systems have been installed in many Air Force training centers. According to unpublished Air Force data, the use of student response devices in the classroom results in

[1] For an example at the college level, see Leland L. Johnson, Cable Television and Higher Education: Two Contrasting Experiences, R-828-MF, The Rand Corporation, September 1971.

(1) greater attention and retention on the part of students, and (2) immediate feedback to instructors on how well the students understand the presentation, which is helpful in pacing and modifying classroom presentations.

A subscriber response unit could provide similar feedback from television students in the home. This would seem to be particularly important to teachers and instructional television producers who now face an invisible audience of unknown number, interest, and understanding. However, not enough experience has been gained to project either the educational value of student feedback or the demand for interactive instructional television from cable system subscribers.

SPECIAL CHANNEL SELECTION

Limited access or subscription programming appears to be one of the new services most likely to achieve early commercial success. Special channels can be made available on a one-way cable television network through the use of signal encoding or special converters. More sophisticated techniques are available in a two-way system.

With a narrowband response unit, a subscriber could key in his request to view special programming. This might be a first-run movie for which an extra charge would be made, or a limited access channel. Policemen might have special information channels in their homes that were unavailable to the general public, for example, or physicians might subscribe to a medical channel. The central computer would receive the request, check to see that subscriber was authorized to see the special programming (or had paid his last monthly bill), and then "unlock" access to that channel by sending an appropriate message downstream to the subscriber's terminal. A billing mechanism would also be turned on at the headend to record usage. At the end of the month the subscriber would receive a bill for special channel viewing itemized in the same way as his bill for telephone toll calls.

A two-way response system also could offer flexibility in special channel selection. The headend computer could be programmed to accept "credit card" requests from subscribers away from home, so that, for example, a physician could see a medical education program at a friend's home and have the charge billed to his own address. It also would allow the cable operator to build in as much security as he thinks is needed for limited access channels. Some operators believe that making subscription channels available at every subscriber's receiver and simply billing for use would be best. Others think that the temptation to receive these channels by bypassing the subscriber terminal would be too great (and technically too easy), so that a switch controlled from the headend must be installed to enable tuning of special channels. Still others believe that signal encoding and decoding would also be required. Each additional level of security costs more money, of course, but if two-way capability is already available, the marginal cost of providing access to special channels should be less than it would be in a one-way cable system.

SENSOR SURVEILLANCE

Up-to-date information from sensors at the subscriber's location can be polled and recorded automatically through a two-way subscriber response system. Audience counting by monitoring the television receiver on-off and channel selection switches is one example. Others often mentioned are meter reading, alarm monitoring, traffic surveillance and control, and control of the cable network itself.

Meter Reading and Utility Load Adjustment

Automatic meter reading has been widely discussed as a way of reducing utility operating costs and increasing billing speed and accuracy. A cable system with two-way response capability could be readily used for this application. Digital encoding devices attached to utility meters would be connected to the subscriber's response unit. Upon command from the polling computer, the meter readings would be transmitted in digital form to the headend and recorded on magnetic tape. The tapes could then be used directly for customer billing. It would be possible to read meters on a weekly or even daily basis, but there is little economic incentive for doing this at the present time.

Encoding devices are currently available for \$20 to \$50 per meter, including installation.[1] Field trials using telephone lines have been successfully conducted,[2] and there is no doubt that automatic meter reading would be feasible on cable networks as well. The problem today is principally one of cost. Despite higher labor rates, increased numbers of "lock-outs," and concern for the safety of utility employees in some urban areas, the cost of reading a meter in the conventional way averages only \$1.50 to \$2.00 annually.[3] One must add to this the roughly comparable cost of transferring handwritten readings into digital data for customer billing. But the total barely justifies even a \$25 capital investment per meter amortized over ten years. There would be little margin left for the cable operator.

Moreover, remote transmission via the cable television network must compete with other automatic meter reading techniques such as transmission over telephone circuits or electric power lines, and reradiated reception by a passing van or airplane.[4] The cable network would seem at some disadvantage compared with these other methods because of its limited coverage -- utilities would prefer to use the telephone network with more than 95 percent penetration than a cable system with 50 percent penetration -- but cable should have relative advantages in speed and accuracy. All of these techniques are being developed, of course, because many people see a large market for automatic meter reading in the future. Two-way cable television networks will have some role in that market.[5] But automatic meter

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[1] H. J. Moeller, "Meter Reading -- State of the Art," Proceedings of the 19th Annual National Cable Television Association Convention, June 1970, pp. 763-786; and H. C. Balwin, Jr., "Meter Reading Out in the Street," Communications, June 1971, pp. 20-26.

[2] C. W. Porter, "Ma Bell's Automatic Meter Reading System -- Maybe," Communications, June 1971, pp. 27-31.

[3] H. J. Moeller, "Meter Reading -- State of the Art."

[4] As described in the articles by Porter and Balwin cited above, and in Business Week, January 30, 1971, p. 5; and Telecommunications Reports, June 22, 1970, p. 47.

[5] Automatic meter reading by cable could be particularly attractive in a "New Town" where it could be designed-in for all residents from the beginning.

reading does not appear to offer significant revenues to most cable television systems in the next five years.

Perhaps a more important service to electric utilities could be the automatic adjustment of total utility load by selective on-off switching of subscriber appliances.[1] The Detroit Edison Company, for example, has experimented with radio-controlled switches costing about $45 each for consumer water heaters.[2] The consumer receives a lower rate if he agrees to let the utility disconnect one of his two water heater elements during peak power periods. By partly controlling overall load, Detroit Edison estimates it can save money by not installing peak-load generating equipment or importing expensive, peak-load power. Additionally, the threat of blackouts or brownouts is significantly reduced. Power load control should be feasible at low marginal cost on a cable system if a subscriber response terminal is already in place. Moreover, this would allow selective, programmable control of units to be turned on or off.

Alarm Monitoring

One immediate home and business service for two-way cable systems is fire and burglar alarm monitoring. Sensors connected to the subscriber response terminal could automatically send an alarm to the central computer when a fire or intrusion occurs. The computer would be programmed to transmit the alarm and address information immediately to the proper fire or police station, or to a private security office.

Security services using telephone lines to transmit alarms to a central office have been available for many years. Typically, the communications cost for these services runs $5 to $10 per month, or about 20 to 30 percent of the total price (the cost of sensors and other security equipment for an average house runs around $1,500,

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[1] F. R. Eldridge, "Uses for Two-Way Polling/Control Terminals in Cablecasting Systems," The MITRE Corporation, WP-7584, May 1971.

[2] J. B. Oliver, "Radio Control of Water Heaters and Distribution Station Voltage Regulators," paper prepared for the IEEE Summer Power Meeting, June 22-27, 1969.

according to a recent article).[1] The chief problem for remote alarm services has been the extremely high incidence of false alarms -- sometimes as high as 98 percent -- which has prompted many police and fire departments to refuse to receive alarms directly from residences and small businesses. Use of the cable television network would not be expected to reduce the false alarm problem appreciably, but cable transmission should be cost competitive with present telephone tariffs. At least one private security company advertises alarm services today with transmission via a cable television network.[2]

Community Applications

The use of remote sensors for municipal purposes such as automated traffic control, automatic vehicle identification, and environmental monitoring is likely to increase significantly in this decade. These applications would be fully compatible with a narrowband, subscriber response cable system, and transmission by cable should be quite competitive with telephone circuits on a marginal cost basis. Municipal communication needs may in fact provide a principal reason for installing cable in downtown business areas.

Cable System Monitoring and Control

A useful service made possible by narrowband response capability would be continuous monitoring of critical components in the cable system itself. At present, such problems as gradual degradation of an amplifier in a large cascade or line unbalance due to temperature fluctuation are quite difficult to isolate and correct. But deviations from normal operation could be quickly identified by the polling computer if sensors were placed on critical system components. Automatic adjustment of amplifiers and other electronic devices also should be feasible in a two-way system.

The ability to disconnect and reconnect subscriber service from the headend may prove important to cable operators. Today, an installer

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[1] The Wall Street Journal, November 3, 1970, p. 1.

[2] Television Digest, April 19, 1971, p. 5.

must be sent out for disconnects and reconnects at a cost to the cable system of $5 to $15 each. If subscribers move or terminate service at a rate of 15 percent each year, the system's annual operating cost is thus increased by between $.75 and $2.25 per subscriber -- a not insignificant amount. This would appear to justify the small added cost -- probably two to three dollars -- of a remotely controlled on-off switch in each subscriber response unit. A headend-controlled video scrambler might also be included for use as an intermediate step before disconnection when a subscriber's bill remained unpaid.

IV. THE ECONOMICS OF SUBSCRIBER RESPONSE SERVICES

In this section costs and projected revenues for the narrowband, subscriber response services outlined in Section III are discussed.[1] The general reader may wish to skip the detailed cost calculations of the next few pages and move directly to the discussion of total equipment costs on page 62.

Cost calculations are based on the following assumptions for a medium-sized cable television system:

1. The cable system passes 20,000 homes and has 10,000 subscribers, 5,000 of whom will receive two-way services.

2. The entire system will be constructed initially with two-way transmission capability. The cable plant consists of 200 strand miles (100 homes per mile). One-third of the strand miles require both 3/4" trunk and .412" feeder cables; two-thirds require feeder cable alone (a feeder-to-trunk ratio of 3). The 3/4" trunk has three amplifiers per mile; the .412" feeder has four amplifiers per mile but has no more than two line extender amplifiers in cascade.

3. Upstream bandwidth will be provided for narrowband subscriber response services including audience counting; subscriber polling; interactive programming; selection of special subscription channels; and provision for installing alarms, remotely controlled switches, and other peripheral devices. These services all use time division multiplexing techniques for computer polling and low-bit-rate digital responses. Other two-way video, voice, and data services that may require more upstream bandwidth are not included here.

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[1]Basic cost data were obtained from Ameco, Inc.; Cas Manufacturing Co.; Cascade Electronics, Ltd.; Digital Equipment Corporation; Electronic Industrial Engineering, Inc.; General Telephone and Electronics Corporation; Hughes Aircraft Corporation; Jansky and Bailey; Jerrold Electronics Corporation; Kaiser Aerospace and Electronics Corporation; Malarkey Taylor Associates; Rediffusion International Ltd.; Scientific-Atlanta, Inc.; Times Wire and Cable Co.; Vicom Industries, Inc.; Visual Information Systems; and other sources. However, the cost estimates presented here are the sole responsibility of the author.

Added capital costs are estimated for the upstream transmission plant, headend equipment, and subscriber terminal.

TWO-WAY TRANSMISSION COSTS

Several options are now available for providing an upstream return link from subscriber to headend:

1. Wire pairs.
2. Upstream transmission on the same cable used for downstream video.
3. A separate coaxial cable carrying upstream signals only.
4. Separate trunk cables, common feeder cables.
5. A switched distribution system, using wire pairs or coaxial cable.

These alternatives are discussed below, and cost estimates for each are compared in Table 3.

Wire Pairs. The existing telephone plant would provide a low cost data return link when relatively few terminals are needed or when data transmission does not interfere with other telephone uses. Thus the primary residential phone line could be used for meter reading in the early morning hours. A cable television response device is likely to be connected to the central computer facility for several hours a day, however. Such use of telephone lines on a dial-up basis by several thousand subscribers could quickly tie up telephone central office equipment. Moreover, the subscriber would not want to have his phone unavailable for other calls while it was connected to the cable television response system. Therefore, a second phone line, for the cable return link, would have to be installed in each home. It would be a party line serving all two-way subscribers, but such leased lines are expensive even with a local area -- typical monthly rentals run about \$4.00 per mile plus \$5.00 per drop. Under present telephone tariffs the cost to link 5,000 homes with the headend in this manner would be prohibitive.

Table 3

ADDED COST OF TWO-WAY TRANSMISSION FOR A 200 MILE CABLE SYSTEM

Two-way Option	Added Cost in Dollars: Trunk	Added Cost in Dollars: Feeder	Added Cost in Dollars: Taps and Drops	Total Cost	Cost Per Mile
1. Wire pairs	17,000	36,000	25,000	$ 78,000	390
2. Single cable FDM	41,000	125,000	0	166,000	830
3. Separate cables	84,000	191,000	50,000	325,000	1,625
4. Separate trunks, FDM on feeders	84,000	125,000	0	209,000	1,045
5. Switched distribution system	-	-	-	425,000-900,000	

The cable operator could install a separate wire pair for the return link, as suggested by Comanor and Mitchell.[1] Technically this is the same as using a wire pair furnished by the telephone company, but the cost estimate is based on installed cost rather than on telephone tariffs. Comanor and Mitchell assume a cost of $180 per mile if the return wires are installed along with the downstream cable. The subscriber tap and drop might add an additional $5 per subscriber if installed at the same time as the cable drop.

Since attenuation on an open wire pair is much greater than on a coaxial cable, this approach would be feasible for short distances and low data rates. A 500 KHz baseband return link, adequate for 5,000 subscribers, might require trunk amplifiers every 1-1/2 to 2 miles (AT&T installs amplifiers every 2/3 mile for 1 MHz Picturephone signals transmitted over wire pairs). Serving 50,000 subscribers with a 5 MHz return channel would require special pairs and amplifiers every 1/2 to 3/4 mile, as is done for the Rediffusion switched system. Amplifier costs are not included in the Comanor-Mitchell estimate. Assuming that an $80 amplifier is required for every mile of trunk adds $80 per mile to the return wire-pair trunk cost. No return amplification is assumed on feeder lines.

Such use of wire pairs for a large, party-line, digital return link has, to my knowledge, not yet been proved out in the field. (A return pair installed in one cable system has not been used for subscriber response services.) Pickup problems might be severe for open wire aerial plant, for example. Moreover, the upstream bandwidth would be severely limited compared with the alternatives that use coaxial cable return links.

Cost estimate:

Trunk wire	- 67 miles @ $180/mile	$12,000
Trunk amplifiers	- 67 miles @ $80/mile	5,400
Feeder wire	- 200 miles @ $180/mile	36,000

[1] W. S. Comanor and B. M. Mitchell, "Cable Television and the Impact of Regulation," pp. 209-210.

Feeder amplifiers	-	0
Connections and drops	- 5,000 @ \$5/subscriber	25,000
Total cost		\$78,400

If one assumes a basic cost per mile of \$5,000 for single cable transmission plant in urban cable systems, this alternative would add only \$392 per mile, or less than 8 percent, to the cost of one-way transmission. Nevertheless, although it would be useful to test the feasibility of wire pair return links, this cannot now be said to represent a conservative engineering approach to the provision of two-way subscriber services.

Two-way Transmission on One Cable. Frequency division (FDM) and space division (SDM) multiplexing of upstream and downstream signals are the two principal approaches to two-way transmission on cable. Most frequency division schemes assume that the return signals will be carried at sub-VHF (5-30 MHz) frequencies on a cable carrying downstream video, although some systems are experimenting with a wider (5-108 MHz) upstream band. For either case, filters would be required at each amplifier station (trunk and feeder) to separate the upstream and downstream signals. Because of the lower attenuation at sub-VHF frequencies, upstream amplifiers need be placed only in every third trunk amplifier station[1] and in one of the two line extender amplifiers assumed as the maximum cascade in each feeder line. The added labor cost is assumed to be only 10 percent of the typical \$2,500 per mile labor cost for installing a single trunk cable. Tap and drop costs should be no higher than for a one-way system.

Although frequency division multiplexing of upstream and downstream signals on a single cable is certainly feasible, the effects on system performance are not fully known at this time. For example, what distortion of downstream video will be introduced by the filters necessary to separate upstream and downstream signals? To what extent are amplifier spacing and the limits on amplifier cascading affected? Some preliminary answers to these questions from demonstrations and field tests now underway are discussed in Section V.

[1] Some manufacturers include a lower gain return amplifier at each station.

Cost estimate:

Trunk cable	-	$ 0
Trunk filters and station modifications @ $70 (67 mi. x 3 x $70)	-	14,000
Trunk amplifiers @ $150 (67 mi. x 1/3 x 3 x $150)	-	10,000
Feeder cable	-	0
Feeder filters and station modifications @ $70 (200 mi. x 4 x $70)	-	56,000
Feeder amplifiers @ $90 (200 mi. x 1/2 x 4 x $90)	-	36,000
Added labor cost @ $250/mi.	-	50,000
Taps and drops	-	0
Total cost		$166,000

Expressed in cost per mile, two-way FDM capability would add about $830 per mile, or around 17 percent, to the cost of a one-way, single cable distribution system.

Return Transmission on a Separate Cable. Dual trunk and feeder systems now are built to provide twenty or more one-way video channels at a cost 40 to 60 percent higher than that for a single cable system. Generally both cables carry downstream signals. However, in some cases it may be possible to use the second cable for return signals only, at least until the demand for downstream channels requires frequency diplexing. This may be particularly useful for experimental field tests of two-way services. But since most dual cable systems use or anticipate FDM operation on at least one cable, the cost attributable to two-way transmission is still the FDM cost detailed above.

An alternative approach would be to add separate trunk and feeder cables, dedicated for upstream signals only, at the same time the downstream cables are installed. Smaller cables could be used, and no filters would be necessary. The major costs would be cable, additional labor (here assumed to be 25 percent of the $2,500 per mile labor cost for installing a single cable), and the taps and drops required. A 10 percent waste allowance is included in the cable cost.

Cost estimate:

Trunk cable (.412") @ $433/mile (67 mi. x $433 x 1.1)	—	$ 31,900
Trunk amplifiers @ $150 (67 mi. x 1/3 x 3 x $150)	—	10,000
Feeder cable (.340") @ $328 (200 mi. x $328 x 1.1)	—	72,200
Feeder amplifiers @ $90 (200 mi. x 1/2 x 4 x $90)	—	36,000
Labor @ $625/mile	—	125,000
Taps @ $3/subscriber	—	15,000
Drops @ $7/subscriber (material plus marginal labor)	—	35,000
Total cost		$325,100

The cost per mile is thus $1,625, or nearly double that for single cable FDM transmission. Yet this cost might be justified in some applications where very low error rates were necessary or where the downstream distortion from FDM transmission could not be tolerated.

Separate Trunk, Single Feeder. The high cost of separate feeders, taps, and drops shown above suggests the use of FDM for two-way transmission on feeders along with a dedicated trunk for upstream signals.

Cost Estimate:

Trunk cable (.412") @ $433 (67 mi. x $433 x 1.1)	—	$ 31,900
Trunk amplifiers @ $150 (67 mi. x 1/3 x 3 x $150)	—	10,000
Labor @ $625/mile (67 mi. x $625)	—	41,900
Feeder cable	—	$ 0
Feeder filters and station modifications @ $70 (200 mi. x 4 x $70)	—	56,000
Feeder amplifiers $ $90 (200 mi. x 1/2 x 4 x 90)	—	36,000
Labor @ $250/mile (133 mi. x $250)	—	33,300
Taps and drops	—	0
Total cost		$209,100

This would reduce the cost to $1,045 per mile, about 20 percent more than that for full FDM transmission. Other combinations of FDM and separate cables are possible, of course.

Switched Distribution System. A switched distribution system, such as the Rediffusion or Ameco DISCADE systems, offers a quite different approach to two-way cable communications. In these systems, a subscriber selects a downstream channel using a telephone-like dial or keyboard terminal. The selected signal is then switched onto the subscriber drop at a local switching center. The line from the home to the switching center (either a small coaxial cable or wire pairs) carries both upstream and downstream signals. We assume here that upstream signals from the switching centers to the headend are transmitted on a separate trunk cable.

To determine the added cost of two-way capability via a switched distribution system, one must first estimate the difference in cost between switched and conventional one-way systems, and then add the cost of two-way transmission on the switched system. One recent study estimates that the Rediffusion and Ameco distribution systems would cost about $220 and $135 per subscriber, respectively, for subscriber penetrations near 100 percent.[1] These do not include the pro-rated costs of headends, origination studios, or other fixed facilities. The figures compare to Rand's estimate of $75 per subscriber for a conventional, single cable distribution system with 100 percent penetration and a density of 100 homes per mile.[2] Thus the cost differential between switched and conventional one-way systems would be $60 to $145 per subscriber (the switching equipment itself costs $60 to $75 per subscriber). Adding two-way capability to the switched system would then require modifications at the switching centers plus a separate return trunk. The switch modifications are assumed to cost between $10 and $20 per subscriber.

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[1] L. L. Stine, C. M. Plummer, and M. A. Lambert, Local Distribution of Telecommunications: A Perspective, The MITRE Corporation, M71-91, August 1971.

[2] Based on installed costs of $5,000 per mile of transmission plant plus $25 for each subscriber drop. No headend or other fixed facilities are included.

Cost estimate:

Trunk cable (.412") @ $433/mile (67 mi. x $433)	- $ 28,800
Trunk amplifiers @ $150 (67 mi. x 1/3 x 4.1 x $150)	- 13,600
Labor @ $500/mile (67 mi. x $500)	- 33,000
Switch modifications (5,000 x $10 -20)	50,000-100,000
Added cost of one-way switched system (5,000 x $60-$145)	300,000-725,000
Total cost	$425,000-900,000

It is not really fair to attribute all the added cost of a switched distribution system to providing two-way capability, since the switched system has other advantages (and disadvantages) for downstream services. Nevertheless, the high cost compared with other options suggests that a need for two-way transmission is not itself sufficient to justify a switched distribution approach.

The add-on costs of these six transmission options are compared in Table 3. At present the frequency division and separate cable approaches, or some combination of them, seem best on the basis of cost and expected performance. Using these approaches, two-way transmission capability adds roughly 15 to 30 percent to the $5,000 per mile cost of single cable, one-way transmission. This represents the added cost to meet the FCC's proposed requirement of two-way capability for cable systems in the 100 largest markets.

HEADEND AND SUBSCRIBER EQUIPMENT COSTS

Central Computer Facility

The schematic drawing for the central computer facility was shown in Figure 4. Although 5,000 two-way subscribers are assumed initially, the central facility should be expandable to serve an order of magnitude more. It is assumed that each subscriber is polled every five seconds and can return 50-100 bits to the computer, but these parameters are not crucial to costing. Several different polling schemes are feasible.

Private discussions with communications equipment manufacturers and computer companies indicate that hardware cost estimates for the central computer facility run $40,000 to $120,000, depending particularly on the peripheral equipment required. A fully equipped headend might include separate minicomputers for data processing and communications control, so that record keeping and processing of return data could be handled on-line, independent of the polling and recording functions. A substantial file record for each subscriber would be stored on discs, and cumulative subscriber responses could be displayed in real time on video or hard copy terminals. Such a configuration would cost approximately $100,000. A simpler headend facility, using only one computer, fewer peripherals, and less memory, could be assembled for under $50,000.

Design and computer software costs to put the first few systems in operation are estimated at $150,000 to $250,000 by companies now developing them, but these estimates seem low in comparison with previous computer system experience. Once such systems are debugged and reliably serving several thousand subscribers, however, the software cost to replicate them in other places should drop to $15,000 to $25,000 per system.

Hardware and software costs for the central facility are relatively fixed, increasing only slowly with increasing numbers of subscribers. Thus on a per-subscriber basis, the central facility cost will dominate overall costs for a small system but will rapidly become less significant for larger systems. The central facility would represent less than 10 percent of total cost for the 5,000 subscriber system. Even including $200,000 for software development, it would still represent less than 25 percent of total costs.

Subscriber Terminal Equipment

The subscriber response terminal receives data directly from the subscriber and from sensors in the subscriber's home. When polled by the central computer, the terminal transmits its data to the headend. It also may perform functions by computer command such as enabling or disabling a special channel. Figure 6 shows a schematic drawing of the subscriber terminal. Its basic components include an rf receiver and demodulator, address decoder, modulator and transmitter, central control logic, and interfaces with the television receiver, various sensors, and controlled peripheral devices. A separate box may contain the subscriber response buttons or keyboard, the channel selector, and a video converter, or all may be included in a single unit.

Although such a device is well within the state of the art, costing the terminal is difficult since none has been manufactured in quantity. Companies building or designing subscriber terminals at the present time have quoted prices between $200 and $300 for tens of units, but their actual cost in small quantities may be considerably higher. Yet many manufacturers expect costs to drop to $100 or less (some would say below $50) in quantities of more than 10,000. The estimate used in this report is that 5,000 terminals would cost the user between $100 and $250 each in one to three years, dropping to $75–$200 by 1976.

TOTAL EQUIPMENT COST

Taking the single cable FDM or separate cable transmission schemes as the most feasible on the basis of expected cost and performance, one arrives at estimates of add-on capital cost for the narrowband subscriber response capability as shown in Table 4. The fixed cost of headend and transmission facilities would amount to between $12 and $24 per household, or a 16 to 32 percent added cost per household above that for a single cable, one-way system.[1] This would more than satisfy the FCC's proposed new rules for two-way capability in the major markets. But providing two-way <u>services</u> rather than <u>capability</u> requires a much larger investment in subscriber terminal equipment. The cost of the subscriber

[1]Based on a density of 100 homes per mile and installed costs of $5,000 per mile plus $25 per drop, giving a total of $75 per household for the one-way system. The one-way system cost would be $125 <u>per subscriber</u>, assuming 50 percent penetration.

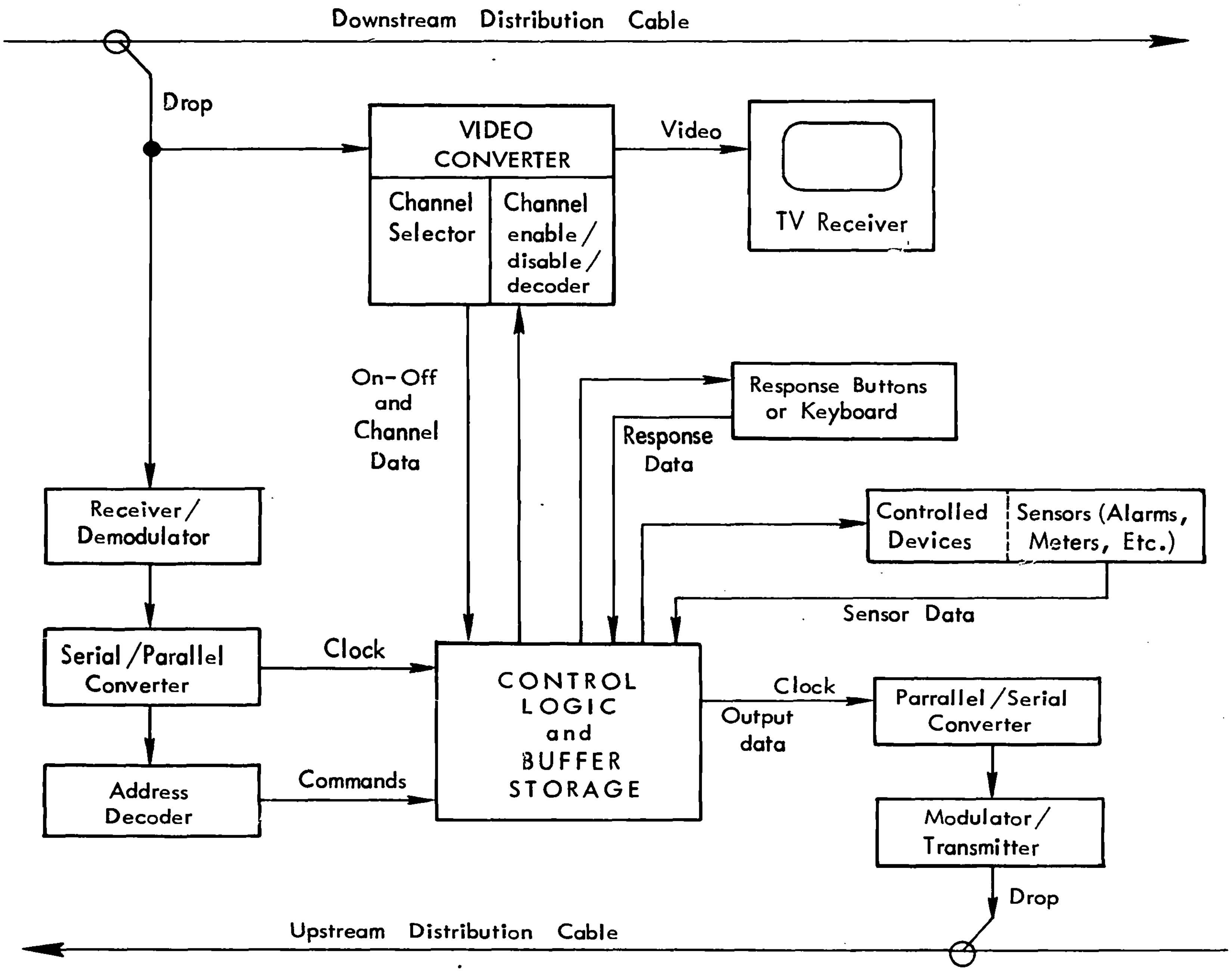

Fig. 6—Subscriber terminal for subscriber response system. This schematic assumes a separate return transmission line, but a single cable could be used for transmission in both directions.

terminal is dominant in Table 4, and uncertainty in the terminal cost is by far the most important reason for the wide spread between "high" and "low" estimates. These estimates also do not include the cost of other devices in the home, such as fire alarms or utility meter transducers, that may be needed for specific services. Finally, the cost per subscriber is quite sensitive to subscriber penetration at low penetration levels, as shown in Figure 7.

Table 4

ADDED EQUIPMENT COSTS FOR NARROWBAND SUBSCRIBER RESPONSE SERVICES

	Low Estimate	High Estimate
Central computer facility	$ 50,000	$ 100,000
200-mile upstream transmission facility	166,000	325,000
System engineering and computer software	15,000	25,000
Subtotal	$231,000	$ 450,000
5,000 subscriber terminals	500,000	1,250,000
Total	$731,000	$1,700,000
Cost per two-way subscriber	$146	$340

It is tempting to try to lower the per-subscriber cost estimates by implementing on a larger scale. If 30,000 subscribers were served by a single headend computer, the per-subscriber cost of headend equipment, system design, engineering, and software should be well below $5. Further, the production cost of the subscriber terminal undoubtedly will come down as large quantities are manufactured. A price of $50 per terminal could give a total added capital cost of $80 or less per subscriber for two-way capability. But these are clearly extrapolations. At the present time no equipment manufacturer is tooled-up to produce subscriber terminals in large quantities, nor is there any field experience with more than ten or twenty terminals operating at one time. Scaling-up to two-way systems with tens of thousands of subscribers will require extensive field tests over several years.

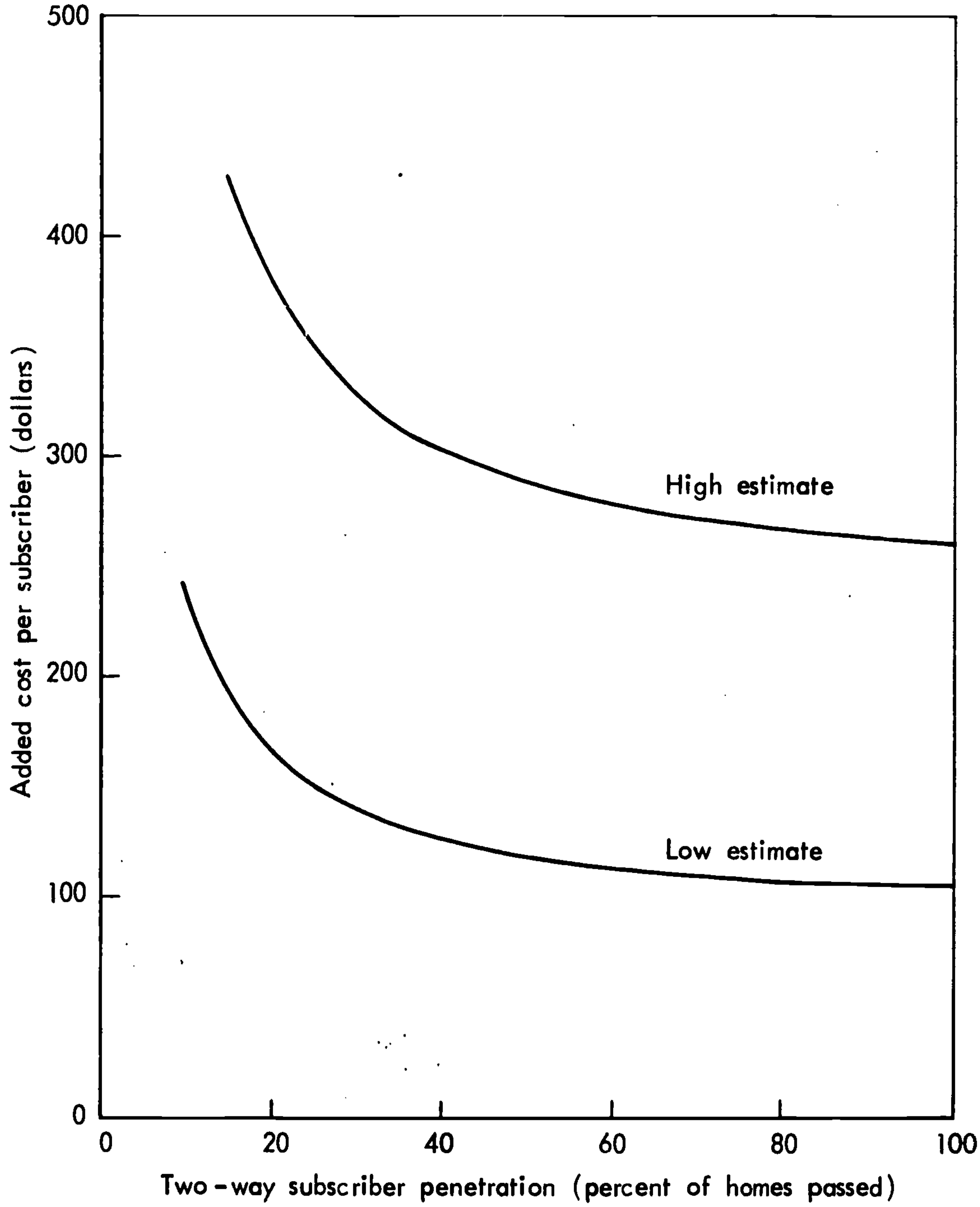

Fig. 7—Added hardware cost for two-way services as a function of penetration

Some manufacturers have suggested that the equipment costs to implement a single two-way service -- alarm monitoring, for example -- might be considerably less than those shown in Table 4. However, this approach does not appear to offer substantial savings. The cost of system engineering and software for a single service might be significantly below that for a multiservice system, but the central polling and recording equipment needed would be about the same. Upstream transmission cost would be unchanged. And although some components and logic circuits in the subscriber terminal could be eliminated (a keyboard would not be needed for alarm monitoring, for example), the installed terminal cost probably would not drop more than 25 percent. Even if only a single service were offered initially, it seems more likely that cable operators would want subscriber equipment that could accommodate additional two-way services as they proved feasible.

OPERATING COSTS

The added cost of operating a two-way system itself should eventually be low, but a considerable amount of maintenance and technical evaluation will be needed in the first few years. One way of estimating the maintenance costs to be expected for the two-way transmission plant is to extrapolate from telephone company experience and projections for "typical" one-way cable television systems. These are presented in Table 5. From this table one might project increased maintenance charges for headend equipment and two-way transmission plant of 5 to 7 percent of the added capital investment. The cost to maintain the subscriber terminal is more critical and, at present, unknown. One cannot simply extrapolate from known maintenance costs for telephone handsets, since they represent much simpler devices. Some representative maintenance costs for television receivers, electric typewriters, and computer printers are also shown in Table 5. In general, higher maintenance costs are associated with consumer items. A 10 percent annual maintenance cost for the subscriber terminal would seem a reasonable estimate at this time.

Similar arguments can be used to estimate depreciation for the two-way hardware. The electronic components in the two-way transmission

Table 5

ANNUAL MAINTENANCE COSTS FOR COMMUNICATION SYSTEMS AND TERMINALS

Item	Annual Maintenance Cost as a Percentage of Undepreciated Capital Investment
Systems	
AT&T total plant[a] (1970)	6.5
GT&E total telephone plant[b] (1970)	4.5
12-channel cable television distribution system[c]	7.0
24-channel cable television distribution system[d]	6.4
Terminals	
Color television console[e]	11.3
Monochrome television console[e]	14.0
Computer printer[f]	5.5
Electric typewriter[e]	7.5

[a]American Telephone and Telegraph Company, financial prospectus, June 2, 1971.

[b]General Telephone & Electronics Corporation, financial prospectus, September 22, 1971.

[c]Comanor and Mitchell, "Cable Television and the Impact of Regulation," pp. 181-182. Figures are taken for the tenth year of operation and include direct maintenance cost plus labor, fringe benefits, and vehicle costs as a percentage of distribution system capital cost.

[d]Baer and Park, "Preliminary Financial Projections for a Cable Television System in Dayton, Ohio." Figures are taken for the tenth year of operation and include direct maintenance cost plus labor, fringe benefits, and vehicle costs as a percentage of distribution system capital cost.

[e]Determined from maintenance service contracts offered by distributors in the Los Angeles area, September 1971.

[f]W. F. Sharpe, The Economics of Computers, R-463-PR, The Rand Corporation, August 1969, pp. 272-275.

plant may have economic lifetimes of seven to ten years, while any added cable itself should last considerably longer. Overall, a ten-year depreciation period seems reasonable. Headend equipment would have computer-like depreciation periods of six to ten years. Subscriber terminal equipment may well have shorter useful lifetimes -- at least until several generations of terminals have been produced -- but in this report an eight year depreciation period will be assumed.

Interest payments will be required on any money borrowed to finance two-way equipment. Here the interest rate on borrowed money is assumed equal to the opportunity cost of equity capital, so that the debt-to-equity ratio can be ignored. An 8 percent annual interest rate is assumed. Financing two-way services is discussed later in this section.

Other operating costs would be associated with the specific two-way services to be offered, such as audience counting and market surveys for advertisers, alarm monitoring, meter-reading, utility load control, and interactive programming for entertainment and instruction. Since these costs are so difficult to estimate at this time, a wide range between $1 and $4 per subscriber per month will be assumed. Each service also would require substantial start-up and development costs.

REVENUE REQUIREMENTS

Cable operators have foreseen two major financial benefits from two-way subscriber services: greater subscriber penetration and higher system revenues per subscriber. Unfortunately, there is no experience on which to base an estimate of increased penetration from interactive services, or the subscriber demand and realizable revenues from them. However, an estimate can be made of the revenue required to pay for the added investment.

Again one can look to telephone and one-way cable television operations for some comparisons.[1] Table 6 shows gross plant investment

[1]This does not mean that the two industries are comparable, of course, since telephone companies are subject to rate-of-return regulation and cable television operators are not. A regulated industry

Table 6

ANNUAL COSTS AND BREAKEVEN REVENUES
(dollars per subscriber terminal)

	Undepreciated Capital Investment	Maintenance	Depreciation	Interest	Other Operating Cost	Annual Breakeven Revenue
Operating Systems						
AT&T telephone system[a]	530	35	26	10	66	137
12-channel, one-way cable television system[b]	119	n.a.	12	3	31	46
Projections for Two-Way Cable Services						
Subscriber response services						
low estimate	146	13	17	12	12-48	54-93
high estimate	340	31	40	27	12-48	110-152
Subscriber-initiated, "frame stopping" services						
1976 estimates	600	60	75	48	24-96	207-279
	800	80	100	64	24-96	268-340
	1,000	100	125	80	24-96	329-401

Sources:

[a] American Telephone and Telegraph Co., financial prospectus, June 2, 1971.

[b] Cox Cable Communications, Inc., financial prospectus, May 13, 1971.

and current operating results for the AT&T telephone network and for one of the ten largest cable television systems in the United States.[1] Annual breakeven revenue for these systems is equal to the sum of annual operating costs (including maintenance and operating taxes, but excluding corporate income taxes), interest charges, and depreciation. With this revenue the system would earn no profit. The breakeven annual revenue for the Bell System, with a gross plant investment of $530 per telephone, would be $137 per telephone. The 12-channel cable television system, having a gross plant investment of $119 per subscriber, would require annual revenues of $46 per subscriber to break even.

Operating projections for two-way subscriber response services are also included in Table 6, based on the following estimates and assumptions:

annual maintenance (percent of gross capital cost)	
transmission plant	7 percent
headend equipment	10 percent
subscriber terminal	10 percent
depreciation period	
transmission plant	10 years
headend equipment	8 years
subscriber terminal	8 years
interest rate	8 percent
other operating costs	$1-$4/subscriber/month

With these assumptions the breakeven revenue per subscriber appears to be between $4.50 and $13 per month for narrowband response services. These services would require, then, at least as much additional revenue as cable operators usually receive for providing one-way television reception.

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is expected to be more capital-intensive than an unregulated one. See, for example, H. Averch and L. L. Johnson, "Behavior of the Firm Under Regulatory Constraint," American Economic Review, Vol. 52, December 1962, pp. 1053-1069.

[1]American Telephone and Telegraph Co., financial prospectus, June 2, 1971; Cox Cable Communications, Inc., financial prospectus, May 13, 1971.

How would this additional revenue be generated? The subscriber presumably would pay most of it, but advertisers, utilities, and other commercial users would be charged for services of benefit to them. Government funds might support interactive educational programming and other community services, and the cable operator himself might subsidize some entertainment services to build his subscriber base. Table 7 shows these potential sources of revenue for narrowband response services in matrix form.

Two major points can be made from the matrix in Table 7. First, there is insufficient evidence at the present time to fill in any of the "x"s with numbers that would represent monthly charges for narrowband response services. These charges can only be determined in the marketplace. Yet one can state that they must sum to between about $4.50 and $13 per month for the cable operator to break even on his investment in two-way services. Second, it seems unlikely that any single interactive service will justify the added cost of installing two-way capability throughout a cable system. Providing a mix of two-way services, supported by home subscribers, government, and business users, appears to be a better strategy for the cable operator, both in terms of commercial self-interest and in order to best serve the community.

A range of breakeven revenues for subscriber-initiated, frame stopping services also appear in Table 6. It is based on three different estimates for the cost of a frame-stopping terminal in 1976, and an assumption that the operating costs for these services will be between $2 and $8 per subscriber per month. With these assumptions the breakeven revenue becomes $17 to $34 per month -- <u>at least three times the cost of one-way cable television service today and significantly more than the average residential subscriber now pays for telephone service</u>.

FINANCING TWO-WAY EQUIPMENT

The question of who initially finances two-way equipment is an important one. One can assume that the cable operator will pay for the two-way transmission system and most headend equipment in the same

Table 7

REVENUE SOURCES FOR NARROWBAND RESPONSE SERVICES

Service	Home Subscriber	Cable Operator	Commercial Sponsor or User	Government Sponsor or User
Basic charge for two-way service	X			
Audience counting			X	X
Remote shopping			X	
Market surveys			X	
Interactive entertainment	X	X	X	
Subscription television	X			
Limited access channels (e.g., for police and medical use)	X		X	X
Interactive educational programming	X			X
Opinion polling on local issues				X
Meter reading			X	
Utility load control			X	
Alarm services	X		X	
Municipal services (e.g., traffic control)				X
Cable system tuning and control		X		

way as he now finances his other capital investments. As discussed above, this would amount to a 15 to 30 percent increase in his capital costs. For some services, such as alarm monitoring, he might lease his basic two-way capacity to another company that would supply the extra equipment needed at the headend and subscriber's location.

The bulk of the added cost is in the subscriber terminal, however, and the cost of terminals will increase as more sophisticated two-way services (such as frame stopping) evolve on cable. One can look to three principal sources for financing subscriber terminals: the subscriber, the cable operator, or the equipment manufacturer.

Subscriber terminals, like television receivers and other expensive items in the home, might be bought for cash or financed by the consumer himself. Between 1948 and 1968, Americans paid more than $38 billion for 152 million television receivers.[1] Of this amount, more than one-third was obtained from installment loans or related forms of consumer credit. The television broadcast industry's growth in the 1950s was highly dependent on this consumer investment. As another example, electric utilities rely on expansion of consumer credit for financing the appliances that increase their revenues from the sale of electric power.

Yet it seems more probable that cable television subscribers will rent their response units from cable operators rather than buy them individually. Certainly until standards are developed and compatible equipment produced, the cable operator must be able to specify the particular response terminal that will be used on his system.[2] Will the cable operator, then, purchase subscriber terminals as part of his overall plant investment? This would likely double his present per-subscriber

[1]Bureau of the Census, Statistical Abstract of the United States, 1956 through 1969, Washington, D.C.

[2]Clearly there are policy questions here, too, particularly since the telephone companies, under the FCC Carterfone decision, have recently been ordered to interconnect with terminals they do not specify or control. Different rules for the telephone and cable television industries may be perfectly in order, however, since they are at such different stages of development today.

capital cost. Since the availability of both debt and equity investment capital represents a major constraint on the growth of cable systems at the present time, this added burden might severely retard development of interactive services.

Financing of subscriber terminals by the cable operator would be akin to common practice in the telephone industry. There, however, subscriber equipment now accounts for less than 25 percent of total system investment.[1] Cable operator financing of subscriber terminals would move cable television further toward a "system industry" with responsibility for all components of the system -- except for the television receiver. Many observers think, however, that eventually television receivers may be provided by the cable operator, too, as part of his overall service.

A third alternative is for subscriber response equipment to be financed initially by the manufacturer for lease to the cable operator and, eventually, to the subscriber. This is the way most data processing equipment has been financed. If subscriber terminals were obtained in this way, one would also expect to see third-party financing by intermediaries analogous to computer leasing companies.

Whichever methods of financing are employed, the sums involved are impressive. To reach the point at which 25 percent of today's television households were equipped for two-way services, at $200 per household, would require $3 billion. This is well beyond the financial capability of present cable operators and most equipment suppliers to the cable television industry. As is usually the case, small companies with limited resources are among the pioneers in developing this new technology. Of course, one expects the large electronics manufacturers to enter the subscriber response terminal market once the demand for interactive cable services is shown. But even then, availability of capital will be a significant factor in determining the growth of two-way cable services.

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[1] President's Task Force on Communications Policy, Staff Paper One: A Survey of Telecommunications Technology, Part 1, p. 7, 1969.

V. SOME RECENT TWO-WAY EXPERIMENTS ON CABLE SYSTEMS

Two-way subscriber response capability moved from the laboratory to the first cable system field tests in 1971. Two-way amplifiers had been installed previously on a few cable trunk lines to permit video origination at points removed from the headend. In the first seven months of this year, however, several cable systems installed or field-tested two-way equipment designed for subscriber services. These systems are listed in Table 8.

TWO-WAY TRANSMISSION TESTS

Most of these first field tests have measured the performance of two-way FDM transmission on a single cable -- a necessary step before interactive services can be provided. Although tests have been underway for only a few months at most, some early results can be seen:

1. Two-way transmission on a single cable is feasible.
2. Two-way subscriber services will require tighter cable system design and construction than has been the industry practice.
3. Building two-way capability into a cable system from the beginning is considerably easier than retrofitting an existing system.

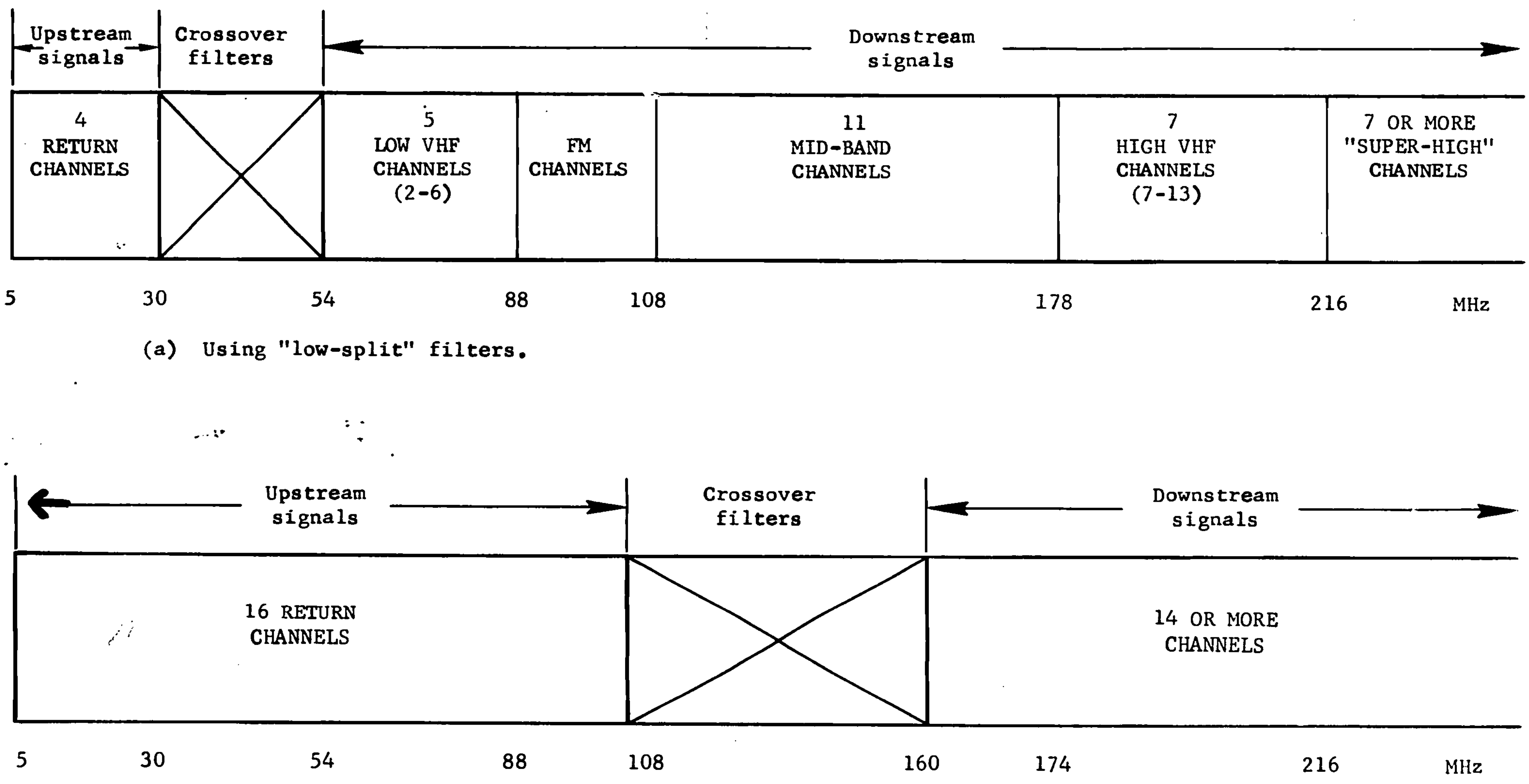
Technical Feasibility

The several field tests show that two-way transmission on a single cable is indeed feasible under operating cable system conditions. Most of the two-way equipment now installed is designed to carry upstream signals between 5 and 30 MHz while transmitting Channel 2 -- the lowest frequency video channel -- in its usual downstream band at 54 to 60 MHz (Figure 8a). This allows upstream transmission of up to 4 video channels. Upstream transmission below 5 MHz is limited by losses in the splitters, couplers, and subscriber taps now available. The range between 30 and 54 MHz cannot be used because of the frequency response characteristics of the filters needed to separate upstream and downstream signals. The

Table 8

TWO-WAY EXPERIMENTS ON CABLE TELEVISION SYSTEMS IN 1971

Location	Corporate Participants	Starting Date	Response Services	Number of Subscriber Terminals in Use (Oct. 1971)
New York City	Sterling Communications Video Information Systems	Feb. 1971	data	12
Los Gatos, California	TelePrompTer Hughes Aircraft Corp. Fairchild Instrument Corp.	June 1971	transmission tests only	
Akron, Ohio	Television Communications Jerrold Electronics Corp.	June 1971	transmission tests only	
Overland Park, Kansas	Telecable Corp. Electronic Industrial Engineering Vicom Manufacturing Co.	June 1971	video, voice, and data	6
Orlando, Florida	American TV & Communications Electronic Industrial Engineering	July 1971	transmission tests only	
Reston, Virginia	Continental Transmission Co. MITRE Corporation	July 1971	"frame stopping" terminal; response via telephone	1
El Segundo, California	TelePrompTer Hughes Aircraft Corp.	Jan. 1972	principally data	∿ 25 anticipated



(a) Using "low-split" filters.

(b) Using "mid-split" filters.

Fig. 8 -- Frequency multiplexing schemes for two-way transmission.

Akron, Ohio system has installed "mid-split" filters, however, that extend the usable upstream band to 108 MHz. As shown in Figure 8b, this would allow transmission of up to 16 video channels upstream, although downstream capacity would be reduced commensurately, of course.

Narrowband response signals from many thousands of subscribers can be accommodated within a single 6 MHz upstream video band. The actual number that can be served depends on the frequency of polling, the number of data bits returned to the headend, and the efficiency with which responses can be multiplexed together. The field tests assume that time division multiplexing techniques will be used for data. Some empty time slots (guard times) will then be required around each response signal so that responses from two subscribers will not interfere. Although experiments to test these limits have not yet been performed, at least two systems transmit return data at a 1 megabit per second rate. This would permit 50,000 subscribers to return 100 bits each to the headend every 5 seconds. Even assuming that half of this capacity is needed for empty guard times or is otherwise wasted, the remaining 50 bit capacity would be more than sufficient for the narrowband response services described in Section III.

Technical Problems

It would be surprising if a number of technical difficulties and "bugs" did not show up in the first field tests of a new development in communications. Two-way cable television transmission is no exception. The two-way field tests listed in Table 8 have encountered a number of problems, including insufficient quality control of cable components, off-air pickup, and degradation of downstream video signals.

Signal quality was not so important in the early days of cable television as it is today. The great demand for television in areas with poor off-the-air reception meant that even a mediocre picture delivered by cable was a vast improvement. Moreover, many cable operators, undercapitalized and eager to build quickly and cheaply, have sought the lowest cost equipment available. Thus, some suppliers of cable television components have adopted less stringent quality control standards than those common in the telephone transmission equipment or data processing industries. These deficiencies soon show up when operators begin two-way FDM transmission on a single cable. The low-frequency response of signal splitters, couplers, and subscriber taps has been found to vary widely in some systems, limiting the bandwidth for transmission of upstream signals. In some cases the cable itself, even when taken from a single reel, has been seriously uneven in transmission characteristics.

Perhaps more important, installation procedures and quality control adequate for one-way television distribution have proved unacceptable for two-way transmission. This has shown up principally in pickup of spurious signals at the lower frequencies used for upstream transmission. Unless the system is tightly connected electrically, the cables themselves can act as good antennas for off-the-air radio signals in the AM band (.5 to 1.6 MHz) and elsewhere. These signals then interfere with upstream response signals. Pickup problems have been encountered by most of the systems listed in Table 8 -- one operator, in fact, reported excellent upstream transmission of Voice of America radio programs when his two-way system was first tested!

The solution to most pickup problems is to check amplifier connections and other points of contact in the system more carefully than has been done customarily. However, an additional source of pickup is the subscriber's television receiver, which is nearly always beyond the cable operator's control. Cable systems may be obliged to install special isolating devices at the receiver to prevent pickup that would garble two-way subscriber responses.

Finally, problems of group delay distortion, signal reflection, and insertion loss have been encountered with the crossover filters used to separate upstream and downstream transmission. Group delay distortion results in a misalignment between brightness and color information on the television screen; reflections give rise to multiple "ghost" patterns; and filter insertion losses lower the overall picture quality at the receiver. All three problems are additive with the number of crossover filters in the line between subscriber and headend, but each can be reduced to a tolerable level by good system design and amplifier adjustment. Knowledge gained from these field tests will also enable manufacturers to design better components for two-way operation.

These technical difficulties can all be corrected in a straightforward manner. Better components can be designed, and better installation practices established. Better qualified technicians can be hired and trained to install two-way cable systems. The distance between two-way amplifiers can be shortened, and the maximum number of amplifiers in cascade can be reduced to limit group delay distortion. All this will, of course, imply higher costs to the cable operator that ultimately will be passed on to cable subscribers. But increased quality control and better system design needed for two-way operation should also improve the quality of downstream television reception as well.

Retrofitting One-Way Systems for Two-Way Transmission

How readily can existing one-way single cable systems be adapted for two-way transmission? One might expect the frequency response and pickup problems discussed above to be far worse in a system already built than in one designed initially for two-way operation. Moreover, most one-way amplifier housings as installed at the present time cannot accommodate the filters and upstream amplifiers required for two-way transmission. This would mean not only the additional expense of new housings and connections, but also added difficulty in "tuning" the system to avoid downstream distortions. Maintenance costs for a retrofitted two-way system might also be high.

Of the field tests listed in Table 8, only the one in Los Gatos, California has seriously addressed this important question. (Three of the other experiments -- those in Akron, Ohio, Overland Park, Kansas, and Orlando, Florida -- have been conducted on newly installed, dual cable plants designed for two-way transmission. The New York City system has not found it necessary to install upstream trunk amplifiers for response signals because of the short distances involved, and the Reston, Virginia experiment uses telephone lines for the return link.) TelePrompTer, the cable operator in Los Gatos, retrofitted 14 amplifiers along 3.9 miles of cable trunk with upstream amplifiers and filters.[1] Transmission tests confirmed that signal pickup, group delay, and reflections caused serious initial problems for both upstream and downstream signals. These could be overcome -- but with considerable cost and effort. Partly as a result of the Los Gatos experiment, and prior to the FCC's announcement of its proposed two-way requirement, TelePrompTer's President stated that the company intends to build dual cable plant with two-way capacity in all future major systems.[2] Other cable operators have indicated similar plans to design new systems with two-way capability from the beginning rather than retrofit at a later date.

TESTS OF TWO-WAY SUBSCRIBER SERVICES

Several of the systems in Table 8 have tested prototype subscriber terminals and demonstrated the kinds of response services that could be offered. Among the services demonstrated have been audience counting, remote shopping, alarm monitoring, opinion polling, and instruction for the handicapped with full two-way voice and video. To date, however, these have been only demonstrations of capability and not real market tests. Not enough subscriber terminals have been available to test the value of or demand for two-way response services.

A demonstration of subscriber initiated services using a prototype frame-stopping terminal is also underway in Reston, Virginia. The terminal, developed by the MITRE Corporation, was described briefly in Section II. Since the Reston cable system does not have two-way transmission capability, the present upstream link from the subscriber to the central computer is by Touchtone telephone. MITRE plans to use the cable network for upstream transmission as soon as two-way equipment is installed.

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[1] S. Edelman, "Cable Communications: The Los Gatos Experiment," The Electronic Engineer, June 1971, pp. 41-44.

[2] H. Schlafly, panel discussion at the 1971 National Cable Television Association convention, Washington, D.C., July 5-9, 1971 (Proceedings to be published).

Subscriber initiated services demonstrated in the Reston experiment include arithmetic drill and practice, a listing of community events, and a telephone number directory. These are just a sampling of the rich mix of information retrieval services that might be provided on such a system. The computer software costs to develop subscriber initiated services will be quite high, however -- in addition to the higher terminal cost -- so that the first real customers for these services will be schools and businesses rather than home subscribers. The Reston experiment shows what may be feasible in the home in the 1980s when a market of several million two-way cable television subscribers has been assembled.

VI. POLICY ISSUES

The previous section underscores the fact that interactive subscriber response services are now in the early stages of development. Some cable systems have installed two-way transmission equipment, and a few prototype response terminals are undergoing field tests. Perhaps more than 100 computer polled, subscriber response terminals will be operating in a single cable system by the end of 1972, although this seems an optimistic estimate at the present time. Yet, although the pace of expansion over the next five years may not be as rapid as enthusiasts would like, we are entering the era of interactive cable television. This final section examines some policy issues raised by the development of two-way services on cable.[1]

THE FCC'S PROPOSED REQUIREMENT FOR TWO-WAY CAPACITY

The FCC has taken an important first step in proposing to require two-way capacity on cable systems. Although not spelled out in the Chairman's letter of August 5, the Commission's intent evidently is to require that upstream transmission capability for data be required in new cable systems within the 100 largest U.S. markets. The Commission would not insist that subscriber terminals be installed or that two-way services be offered immediately by cable operators in major markets.

This seems to be a sensible approach. It would not be in the interest of either the cable industry or the public to force the offering of any specific set of services prematurely. Marketing commercial two-way services, or implementing community services such as interactive education and local opinion-taking, will require step-by-step development of terminal equipment and software over several years. What is important is to ensure that cable systems have the capability to offer two-way services when a reasonable consumer demand or public need for them exists. Although it is likely that most cable operators in large

[1]Other basic issues, such as the value to society of instantaneous political polling and other interactive services are not treated in this report.

cities would install two-way transmission facilities anyway in their own commercial self-interest, the Commission has wisely chosen to require them to take this path. Requiring the additional investment in upstream transmission plant makes the marginal cost to develop and operate new services that much smaller. Operators should then have sufficient incentives to find uses for their two-way capacity.

An important question is whether, or when, cable operators in the major markets should be required to retrofit existing one-way systems. The technical evidence to date suggests that some older one-way systems are entirely unsuitable for two-way operation -- that it would be cheaper to install new cable and two-way electronics than to retrofit the existing plant. These older systems then should be given a fair time period in which to make the necessary changes under the proposed new rules (a situation commonly referred to as "grandfathering"). But how long should present one-way systems be grandfathered? One solution would be to choose a more-or-less arbitrarily fixed time -- perhaps 5 years -- after which all systems would be required to have two-way capacity installed. Another would be to require two-way capacity only when the cable system is physically rebuilt. A third approach would be to link grandfathering to the cable owner's present depreciation schedule for federal tax purposes -- that is, to require upgrading when the cable plant is (say) 90 percent depreciated (but no longer than 10 years). This might add some complication due to different ages and depreciation periods for different parts of the system, but it might be fairer to the cable owner who made his initial investment without knowledge of the Commission's new rules. In any event, early upgrading of one-way transmission facilities in the major markets should be the Commission's objective if it wants to encourage widespread use of two-way services.

TECHNICAL STANDARDS

It would be a mistake to impose rigid technical standards on two-way cable television at this time. The technology is relatively new and untried; there are many technical problems still to be uncovered. Testing different technical approaches and system designs is essential to the rational evolution of new interactive services. Nevertheless, one should begin today to consider the kinds of standards or compatibility requirements that may be appropriate in the near future. These might include:

- Agreement on a frequency band or bands for downstream interrogation of terminals, upstream data responses, shared voice channels, and so forth.

- Definition of one or more standard terminal interfaces, so that terminals from different manufacturers could be used on the same system.

- Definition of the coupling between video program materials and polling sequences, so that producers of interactive video software are not tied to specific hardware. This could be particularly important for the widespread dissemination of instructional programs with feedback, such as, for example, an interactive "Sesame Street."

- Definition of standards for cable system interconnection. Cities with multiple cable franchises would need real-time interconnection for polling and recording citizen opinions during a televised city council meeting, for example.

Basic technical standards for cable television transmission are currently under study, and the FCC has proposed to establish performance standards for the quality of downstream television signals. The Commission has also stated its intent to form "a task force of experts to advise us in designated areas."[1] Assembling such a group of experts to consider standards for two-way services would be a worthwhile next step.

PRIVACY

New services on cable television networks raise two separate issues of privacy. The one that has been the more widely discussed is how signals addressed to a single individual or a special group will be denied to others. Police use of a channel to transmit pictures of "wanted"

[1] FCC Letter, p. 40.

individuals to precinct stations might be one example. Electronic mail delivery or point-to-point transmission of business transactions would be others. The problem arises because all signals are usually available at all points on the party-line cable network. Although an individual subscriber's terminal would be designed to receive only those messages addressed to him, he might be able to alter it cheaply and easily in order to receive his neighbor's mail.

Eavesdropping, of course, would not be unique to cable television; it occurs over telephone lines and in the postal service as well. And the remedies would appear to be the same as those applied to other communications channels: namely, a combination of technical safeguards and legal restraints. Technically, there are a number of ways to deny signals to unauthorized users, including transmission at frequencies not received by standard equipment, scrambling, jamming, and the use of special passwords. Each safeguard involves an additional cost -- implying a different tradeoff between use of the cable system and other modes of communication -- and each can be defeated by an eavesdropper motivated to spend sufficient money and effort to listen in (burglars who obtain the proper radio receivers, after all, can readily listen to police calls). Presumably, the cable operator and users of a particular service should be able to decide what technical safeguards they are willing to pay for. Operators and users of computer systems are today faced with similar decisions. Additionally, laws prohibiting unauthorized eavesdropping and message tampering should be extended to cover cable services as well.

The second privacy issue arises from the data about an individual subscriber that can be accumulated through subscriber response services. With automatic polling and recording equipment, a cable operator could amass a substantial data file on each subscriber, including his viewing habits, his buying patterns, and his political preferences. Should the cable operator then be permitted to correlate an individual's responses from different services? Should he be allowed to keep these data at all? Should he be able to sell them to advertisers, or allow government officials to see them? Should he be obliged to show each subscriber his own file, or inform him when it is made available to someone else?

The FCC obviously has recognized this privacy problem. In its proposed requirement for two-way communications capacity, the Commission states: "Of course, viewers should also have a capability enabling them to choose whether or not the feed-back is activated."[1] Unfortunately the issue cannot be resolved in such a simple manner. Viewers may well want their response device activated in order to purchase a new sewing machine or to take part in a local zoning hearing. It is the cumulation and correlation of such data that pose potential threats to individual privacy. There seems no way to avoid the conclusion that cable television response services could be used to generate sensitive data on individual subscribers and households.

The impact on individual privacy of record-keeping by credit bureaus, market research firms, and government agencies has been the subject of much recent public discussion and scrutiny.[2] Cable television response services should be included in discussions of the privacy issue, and some regulations on the handling and dissemination of response data may be needed. It seems necessary and appropriate for the FCC to face this issue squarely in its continuing review of cable television policies.

For some, two-way cable television services may even conjure up an Orwellian nightmare in which the individual eventually is watched by his television set rather than vice versa. Although remote surveillance of public areas would be feasible with today's cable channel capacity and has been proposed as an important aid to law enforcement,[3] extending surveillance into thousands or millions of homes would be difficult and very costly. It might be possible, but a society bent on destroying individual privacy and freedom probably could find easier ways to do it. Nevertheless, the development of two-way cable services raises possibilities of potential harm as well as potential benefits, just as do all

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[1]FCC Letter, p. 31.

[2]A major study of computer data banks and their impact on individuals has been conducted by the Computer Science and Engineering Board of the National Academy of Sciences, under the direction of Alan F. Westin, for the Russell Sage Foundation. The study is to be published late in 1971.

[3]Communications Technology for Urban Improvement, pp. 122-130.

our urban communities a generation from now as the telephone network is today, some early tests of community services could usefully guide the development of this technology in the public interest.