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ABSTRACT

The results of a survey of cable television (CATV) and related technological industries are summarized. In this, the first of a series of seven reports, attention is focused upon some major technical factors which need to be considered in order that a transition from the technical state of today's cable television and services to new teleservices may be effected. The relationship between systems and teleservices is explored and technical summaries are presented in the areas of measurements, standards or engineering practices, new applications of technology, system design analysis, software, and teleservices. The ensuing volumes will discuss: subscriber terminals and network interface (volume 2), signal transmission and delivery between head-end and subscriber terminals (volume 3), system control facilities (volume 4), system interconnections (volume 5), and the use of computers in CATV two-way communications systems (volume 6). The last report in the series will consist of a selected bibliography. (Author/PB)

OT REPORT 73-13

A SURVEY OF TECHNICAL REQUIREMENTS FOR BROADBAND CABLE TELESERVICES VOLUME 1

OT

U.S. DEPARTMENT OF COMMERCE/Office of Telecommunications

VOLUME 1
A SUMMARY OF TECHNICAL PROBLEMS ASSOCIATED WITH BROADBAND CABLE TELESERVICES DEVELOPMENT

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U.S. DEPARTMENT OF COMMERCE
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July 1973

UNITED STATES DEPARTMENT OF COMMERCE

OFFICE OF TELECOMMUNICATIONS

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FOREWORD

As information transfer becomes more important to all levels of society, a number of new telecommunication services to homes and between institutions will be required. Many of these services may require broadband transmission. The new services may, in part, evolve from those provided by cable television.

This is one of a series of reports resulting from a survey of the CATV industry and related technological industries. The survey identifies some of the important technical factors which need to be considered in order to successfully bring about the transition from the technical state of today's cable television and services to those new teleservices which seem to be possible in the future.

The current and future broadband capabilities of telephone networks are not discussed since they are described in many Bell Laboratory and other telephone company publications. Also, the tremendous load projected for common carrier telephone and data systems in voice and data communication suggests that two-way, interactive, broadband networks, not now in existence, may be required in addition to an expanded telephone network. The many aspects of economic viability, regulation, social demand and other factors that must be considered before the expectation of the new teleservices can be fulfilled are not within the

scope of these reports. These reports concentrate on technical factors, not because they are most important, but because they have been less considered.

A report about the state-of-the-art and projections of future requirements in a complex technology draws material from a vast number of sources. While many of these are referenced in the text, much information has been obtained in discussions with operators, manufacturers, and consulting engineers in the CATV industry. Members of the National Cable Television Association, particularly, have been most helpful in providing information, discussing various technical problems, and in reviewing these reports.

Because of the substantial amount of material to be discussed it was believed most desirable to present a series of reports. Each individual report pertains to a sub-element of the total system. However, since some technical factors are common to more than one sub-component of the system, a reader of all the reports will recognize a degree of redundancy in the material presented. This is necessary to make each report complete for its own purpose.

The title of the report series is: A Survey of Technical Requirements for Broadband Cable Teleservices. The seven volumes in the series will carry a common report number: OTR 73-13. The individual reports in the series are sub-titled as:

A Summary of Technical Problems Associated With Broadband Cable Teleservices Development, OT Report No. 73-13, Volume 1.

Subscriber Terminals and Network Interface, OT Report No. 73-13, Volume 2.

Signal Transmission and Delivery Between Head-End and Subscriber Terminals, OT Report No. 73-13, Volume 3.

System Control Facilities; Head-Ends and Central Processors, OT Report No. 73-13, Volume 4.

System Interconnections, OT Report No. 73-13, Volume 5.

The Use of Computers in CATV Two-Way Communication Systems, OT Report No. 73-13, Volume 6.

A Selected Bibliography, OT Report No. 73-13, Volume 7.

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TABLE OF CONTENTS

A SURVEY OF TECHNICAL REQUIREMENTS FOR BROADBAND CABLE TELESERVICES

A SUMMARY OF TECHNICAL PROBLEMS ASSOCIATED WITH BROADBAND CABLE TELESERVICES DEVELOPMENT

P.M. McManamon and W.F. Utlaut*

This report summarizes the results of a survey of the CATV industry and related technological industries. The following six reports (OTR 73-13, Volumes 2 to 7) deal with the survey results in detail. The survey identifies some of the important technical factors which need to be considered in order that a transition from the technical state of today's cable television and services to new teleservices may be brought about.

The relationship between systems and teleservices is explored. Technical summaries are presented in the areas of measurements, standards or engineering practices, new applications of technology, system design analysis, software, and teleservices.

Key Words: CATV, Cable television, Technical Survey Summary, Technological Impacts on CATV

1. INTRODUCTION

The potential benefits of two-way, interactive, broadband communication networks for home, business, education, and other societal needs in the United States have been identified by many authors. For example, the Committee on Telecommunications of the National Academy of Engineering

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(1971) suggests that there appears to be a significant need for several new networks in addition to the existing telephone network, which is now capable of transmitting voice, data, written materials, and pictures between two points. They indicate that a new network is needed that can distribute information from central facilities to homes and offices, with a capacity of as much as 30 television channels and a limited capacity for return information.

Other very high capacity networks, with bidirectional information transfer, carrying up to 30 equivalent television channels, interconnecting major public institutions and large commercial enterprises are perceived by the committee as needed, as are multipurpose networks for sensing and collecting data around a community for such items as pollution, traffic, and power monitoring. Such networks are not in existence today, and there are major financial, sociological, legal, and technical problems that require solution prior to the development of any of these networks. The problems are all intricate and inter-related.

This report summarizes some of the technical problems that have been identified as a result of a survey made of the CATV and related technology industries. This information is discussed in greater detail in a series of reports and papers resulting from the survey (Wieder et al., 1973; Chadwick et al., 1973; Smith et al., 1973; McManamon, 1973;

Campbell, 1973; Holmberg et al., 1973; Chadwick and McManamon, 1973; Chadwick, 1973). Most of these reports are also listed in the foreword.

Because of the requirement of high information capacity anticipated for new generations of networks, which necessitates using a large frequency bandwidth, the networks that eventually materialize are expected to utilize cable to a large extent. New allocations for over-the-air transmission in the already crowded radio spectrum can not be expected. Thus, the emergence of two-way broadband teleservices will likely be closely related to the growth of cable in major television markets and, possibly, in new rural transmission networks.

For this reason, a major part of the survey from which this report arises was made to understand better the nature of the CATV industry and the technical characteristics of equipment and engineering practices used in today's systems. In addition, since the systems in use today were never intended to provide the range of services which may develop, we found it necessary to explore the possibilities of new technology. Examples are fiber optics and digital techniques for transmission, information compression and multiple-access techniques, developments in computer technology, and large-scale integrated circuits, all of

which may have a profound influence upon the way two-way broadband networks evolve.

The current and future broadband capabilities of the telephone networks are not discussed since information about them exists in telephone company publications. Additionally, the projected load for common carrier telephone and data systems in voice and data communications is so great that those systems must develop vigorously within the decade for those purposes alone. Thus, it is more likely that new networks will come into being if the anticipated demand for new services materializes.

Many of the technical problem areas identified in this report are being addressed, at least in part, by an industry advisory committee appointed by the Federal Communications Commission. This committee, Cable Technical Advisory Committee, consists of about 150 members representing all segments of the cable television industry. Its role is one of technical fact-finding and interpreting technical and economic factors for the Commission. However, C-TAC will play no role in making policy or regulations. The initial charter of C-TAC runs for two years, expiring in mid-1974. It is currently organized into nine panels as follows:

Panel 1 - Measurement Methods and Instrumentation

Panel 2 - Subjective Evaluation of Picture Quality

Panel 3 - TV Receivers for Cable Television

Panel 4 - Class II Cable Television Channels

Panel 5 - Cable Frequency Channeling

Panel 6 - Technical Operations

Panel 7 - Interconnection

Panel 8 - Television System Coordination

Panel 9 - Class III and IV Channels (Bi-Directional).

In view of the above, it is apparent that considerable interest exists in CATV and its future potential, but as discussed in following sections and in the complementary reports, solvable technical problems do exist and attention must be given to them if the full expectations of broadband teleservice networks are to be fulfilled. Many of the problems will be solved by the industry in due course of its evolution. However, if governmental uses or priorities for providing services of the kind which are highly specialized or initially not economically viable are desired at an early time, help and stimulation by government resources may be necessary in addition to support in areas in which government has traditional responsibilities.

2. BROADBAND CABLE SYSTEMS

The cable television industry has evolved and grown over about the past two decades to provide improved conventional television reception by cable systems to rural and urban

communities where direct broadcast signals provide unacceptable picture quality. The number of operating CATV systems has grown from a single system in 1949 to 3079 at the end of July 1972. These systems, which pass by 11 million homes, serve just over 6 million subscribers, as compared to 120 million telephone subscribers. The history of systems growth is illustrated in figure 1. Now that the FCC has relaxed its restrictions on CATV in the top 100 markets, where nearly 85 percent of the households in the U.S. are located, many believe that an enormous growth of cable into homes will occur.

The management and operations of the current systems are quite fragmented. There are a number of multiple system operators (MSO) who operate two or more systems, and there are also independent single system operators. Data in the CATV Directory (1972-1973) show that the largest MSO serves 685,000 subscribers in 172 communities in 33 states, but in many states only one community is served. The top 50 MSO serve 75 percent of the current 6 million subscribers, with the 50th largest serving 19,000 subscribers. The average number of subscribers per system is less than 2500. The largest system, serving San Diego, California, has about 53,000 subscribers, but it is estimated that nearly 50 percent of today's systems have fewer than 500 subscribers.

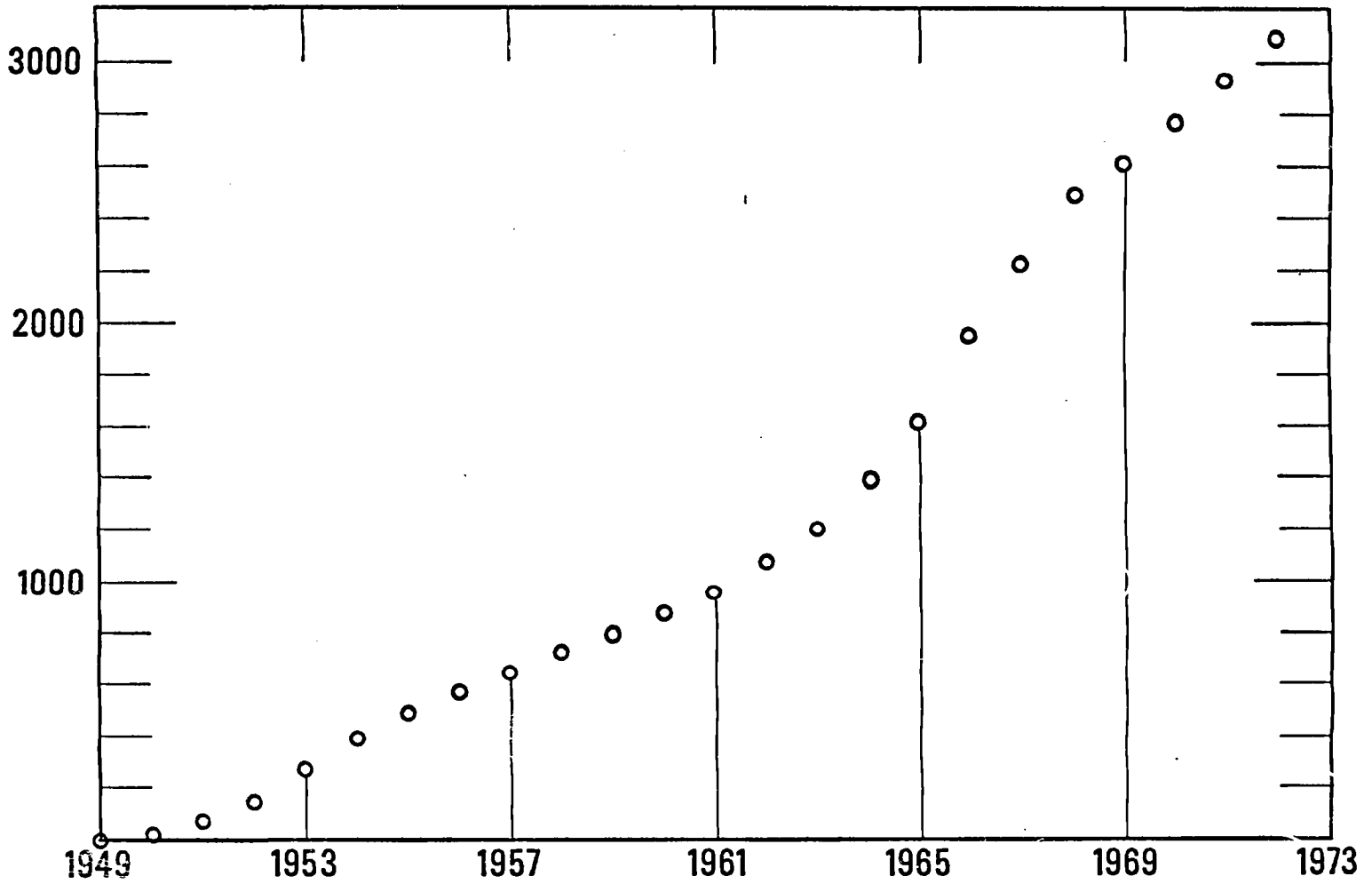

Figure 1. Number of cable systems in the U.S. (Source: CATV Directory 1972-73).

The technical profile of current CATV operating systems, when compared with broadcasting, common carrier, and other telecommunication systems, is probably one of lesser sophistication in spite of the fact that the technical requirements are of the same order of magnitude in most of these industries. Equipment state of development, complexity, and performance appears less advanced in CATV, overall. System design is often done with the assistance of consulting engineering firms or by engineering staffs of CATV equipment manufacturers. Many of the smaller systems do not have adequate test equipment to measure the quality of service provided by the system. For example, in late 1972, the National Cable Television Association, representing a large number of system operators, found it desirable to request a delay for a year of the performance measurements required annually by the FCC because many system operators could not perform the measurements and consulting firms were overloaded.

Two-way interconnection between systems is almost non-existent. Much of the programming that is intended for more than local service is distributed by use of videotape or film. However, the limitations to electronic distribution of cablecasts are being reduced as microwave facilities owned by CATV operators, and specialized common carriers, which can be used for cablecast transmission are increasing.

Short-haul, multichannel, microwave systems and the creation of domestic satellite facilities in the near future will greatly change the possibilities for electronic distribution of cablecasts.

It seems clear that the many CATV systems are satisfactorily performing their intended service of relaying television to areas which would otherwise have only inferior television service. However, with the exception of a few experimental systems, the information on cable now flows in one direction: from the head-end plant, where the program is received as broadcast over-the-air or from a microwave relay (or occasionally originates) and processed for transmission over trunk and distribution lines, to home terminals. The technical emphasis of manufacturers and system operators has been, then, to assure reasonable quality one-way transmission and reception of a few channels of television. Unfortunately, adding return channels for even simple two-way communications involves more than replacing one-way amplifiers with two-way amplifiers and some cross over filters. Much greater sophistication in equipment, network operation, and training of personnel will be required to provide the two-way broadband teleservices envisaged by the NAE telecommunications committee and others. A description of the many services which are envisaged for the future discussed in the next section. The

reader is directed to the references at the end of this report and to four reports in particular which provide a substantial summary of many possible services (Baran, 1971; Baer, 1971) and discussions concerning the realizability of these services (Sackman and Boehm, 1972; McGowan et al., 1971).

Because of the gap between existing cable systems and the requirements for future systems, and the nature of todays industry (its fragmentation, disparity in system size, variation in equipment sophistication, and degree of technical skill), the technical problems discussed in subsequent reports may range from inconsequential to overwhelming as viewed from various vantage points within and outside the industry. These technical problems are summarized to provide an overview of the technical needs for those not caring to pursue the more extensive discussions in the other reports of the series.

Finally, the reader will observe that the summary (section 3) is written as a series of problem area descriptions or technology transfer opportunities. No statements are included nor implied concerning what industry or government agency or both might address the particular problem or opportunity. It is not the purpose of this survey to make such an assessment. The report is intended to stimulate activities in both the industries involved,

concerned government agencies, and private organizations to begin, or continue, to address some of the problems or opportunities. Further, the list of problem areas and opportunities is certainly not to be taken as all inclusive for, as two-way interactive systems develop and grow, other important and perhaps unanticipated problems will most likely arise.

The CATV industry is growing and evolving in such a way that a generally agreed upon definition of a CATV system is difficult to obtain. Each definition has to have numerous exceptions appended. Definition of broadband networks for two-way transmissions appears to have similar difficulties. The traditional one-way CATV system, though, is described by numerous authors.

Rheinfelder (1970) gives a thorough introduction to many aspects related to CATV systems. Sackman and Boehm (1972), Martin (1971), Baran (1971), and Baer (1971) are among many authors who discuss aspects of two-way systems. Shapiro (1972) considers the subject of networking and distribution.

Baer (1971) divides the future cable communication system into six classes, depending on the function each class is designed to perform, and then summarizes possible teleservices each can provide. Table 1 repeats this summary from Baer (1971). The first two classes, one-way broadcast

Table 1. Categories of New Cable Communications Services, From Baer (1971) with Permission

Service Category	Downstream Signals	Upstream Signals	Equipment Requirements: Headend Equipment	Equipment Requirements: Subscriber Equipment
I. One-way broadcast services	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. Additional channels 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. Subscription channels movies entertainment programs instructional programs sports and special events			Signal scrambler or encoder	Unscrambler, decoder or special converter
II. One-way addressed services 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. Narrowband subscriber response services	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. Interactive television entertainment programs instructional programs opinion polling remote shopping municipal services information				A. identification or authorization key
B. Sensor monitoring audience counting alarm monitoring meter reading cable system maintenance				B. channel sensor fire and intrusion sensors meter encoders amplifier and other component sensors

Table 1 (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

and one-way addressed cable systems, are one-direction systems offering video and data services to all or specially addressed subscribers. These two classes can be accommodated into the existing CATV industry. The cost to the subscriber is yet to be determined. Further, some of the services provided by the addressed system might be handled by the telephone network.

The next two classes, subscriber response systems, and shared voice/video systems, can provide limited two-way capability so that subscribers can respond by low-rate data and limited voice and/or video means. These systems could be realized with the current technology of components and system designs. Whether they will be economically viable and can be expanded to meet mass demands is still unknown.

The last two classes, the subscriber-initiated system and point-to-point system, are considered to be extended and full two-way systems, respectively. Both would require new advancements in technology, complicated switching facilities, more sophisticated system designs, and perhaps unified standards of measurement and quality control. The cost to subscribers would be considered high on the surface. However, it is felt that it is rather deceiving to consider the cost alone. The value of the system should also be weighed simultaneously.

In order to place these proposed teleservices and systems into a perspective of existing and experimental systems, some of the more recent two-way systems are reviewed.

Vicom System

This system, developed and manufactured by the Vicom Manufacturing Company, Dexter, Michigan (now Interactive Video of Ann Arbor, Michigan) has been installed and operated at Overland Park, Kansas, on Telecable Corporation's CATV network. It is designed to accommodate both interactive and monitored services. The upstream capability includes video, data, and audio functions under the control of a central computer. The interactive equipment at the subscriber location consists of a 26-channel converter and a terminal containing the digital and RF circuitry. Several peripheral devices can be connected to the terminal on a temporary or permanent basis. Video downstream channels are allocated on the frequency band of 120 to 174 MHz, while the video upstream channels are operated at 12 to 30 MHz. Data downstream and upstream channels occupy, respectively, 110 to 116 MHz and 6 to 10 MHz. The frequency band for the audio downstream is 120 to 174 MHz, and frequencies for the audio upstream are at 5.50, 5.55, and 5.60 MHz. The system is flexible and may offer some privacy provisions if so desired.

Tocom System

This system is being developed by CAS Manufacturing Company of Dallas, Texas. It has not been installed other than in the CAS corporate facility. The system, when completed, can offer regular TV service, home protection, pay television, surveys and rating services, meter reading, cable amplifier monitoring, and subscriber response polls. The downstream transmission has a capacity of 26 TV channels (2 to 13 and A to N), and the upstream transmission is operated at 6 to 30 MHz. Subscriber responses are made through a remote transmitter-receiver unit to be provided by CAS. This unit includes a 26-channel converter, an RF receiving section, a crystal-controlled digital transmitter, and a digital control system. A complete system can be made up of as many trunks as required with each of the trunks accommodating up to 30 groups, each with 999 subscribers. As such, the system is capable of offering services to a large number of subscribers. Each trunk is assigned a specific return frequency, spaced 0.25 to 0.75 MHz apart, so that all 999 subscribers on any one trunk operate on the same upstream frequency.

Subscriber Response System

This system, developed by Hughes Aircraft Company, Culver City, California, has been under field test by TelePrompTer Corp. in Los Gatos, California in a single

cable installation. The system is readily adaptable to dual-cable installations. Two-way communications take place between subscribers' terminals and a computer complex known as a Local Processing Center (LPC). The system has a capacity of 26 video and data channels for the downstream transmission, and data channels only for the upstream transmission. Downstream signals occupy a band of 54 to 270 MHz using pulse code modulation at a data rate of 10^6 bit/sec. Separate digital signals, which are used to frequency-shift-key a 110 MHz carrier, occupy a 4 MHz bandwidth (108 to 112 MHz). Upstream signals, which also use a 4 MHz bandwidth (21 to 25 MHz), are also pulse code modulated at a data rate of 10^6 bit/sec, but the 23 MHz carrier is phase-shift-keyed. At the head-end of the system, the digital signals are frequency multiplexed with the standard video signals and sent downstream through the cable network. At the subscriber's terminal, the composite signal is routed to a modem unit that converts the 26-channel television spectrum to a fixed frequency signal (usually channel 8 or 12) for reception by the television receiver. The modem performs all of the RF modulation and demodulation and most of the signal processing, and also provides the interfaces for all accessories in the system. All operating controls for the subscriber terminal are contained in the subscriber's console connected to the

modem. A console contains a television channel selector switch, a keyboard, and a small strip printer. The system can be used for remote shopping, educational instruction, reservation services, reports, mail and advertising, and data bank access.

TICCIT System (Time-Shared, Interactive, Computer-Controlled Information Television)

This system is being demonstrated at Reston, Virginia, by the MITRE Corporation. It is a dual-cable system supplying each subscriber with 12 regular TV channels on each cable. The existing telephone is used for upstream transmission. The system provides computer-generated information that can be received and displayed selectively by standard TV receivers. The computer facility is physically located at McLean, Virginia. Voice and still-picture signals generated by the computer are transmitted to the head-end of the Reston CATV system by microwave link. The signals are then put into channel 13 of one of the two cables.

At the computer facility, standard telephone lines are terminated in modems that convert subscribers' information requests into a digital format. A character generator provides a standard television signal picture containing up to 800 characters (16 lines of 50 characters each). The character set consists of 96 alphanumerics.

The home terminal uses a standard television receiver, a video tape recorder, and a coupler/decoder. The video tape recorder serves as the refresh memory. The recorder is driven by a composite video signal coming from the coupler/decoder, which also provides some control signals for the recorder mechanism. The coupler/decoder has a television tuner, an IF strip, and a detector so that the recorder can record material from any television channel. If the address of the transmitted picture matches the decoder's address, the recorder is placed in the record mode for the entire picture frame. At the completion of the frame, the recorder automatically is placed back in the playback mode.

When a user requests information from the system, he simply dials the phone number for the computer. It signals automatically with a beep when it is ready for interactive communication. The computer then displays on the TV screen a directory of services and tells the subscriber to depress the number on his push-button telephone corresponding to the service in which he is interested. The system provides capabilities for selective distribution of materials during "off hours". A movie or book or newspaper, for example, could be sent to a subscriber's video recorder to be stored for later display on his television receiver (Mason et al., 1972).

Dial-a-Program System

This system, designed by Rediffusion International, Ldt., is being installed at Dennis Port, Cape Cod, Massachusetts. Basically, it is a switched system whereby program material is supplied to each subscriber independently of the other subscribers on the system. The cables used are not coaxial, but HF twisted pairs. The heart of the system is a central exchange to which each subscriber is connected by two pairs of cables. One carries program signals in either direction; the other carries control signals. At the exchange, a 36-position reed selector switch is dedicated to each subscriber. Each of the 36 positions can be connected to a program source. The subscriber is provided with a telephone-type dial selector switch generating dc pulses to operate the switch in the exchange. When a subscriber wishes to receive a particular program on his regular TV receiver, he dials the code number corresponding to the program material. The dc pulses are sent to the exchange on the control cables. The selector arm on the exchange switch moves to the right position, making the connection between the subscriber and the program source at the head-end in the exchange. The program material is then sent to the subscriber through the remaining pair of cables.

Since the system is simple, any subscriber, given the necessary equipment, can be a program source for all other subscribers on the system. Upstream program signals are in the 9 to 15 MHz band, downstream signals in the 3 to 9 MHz band. Since frequency division multiplexing is used on the programming cables, distortion is not a problem. Another advantage is that it does not need expensive terminal equipment in a subscriber's home. The major disadvantage is that the system needs a central exchange for every 336 connections. The 336-connection limit is partly determined by a restriction on the maximum number of 36-position switches in any exchange and partly by the complexity created by the number of cables between the subscribers and the exchange. The system limits the distance to about 550 meters from subscriber to exchange.

3. SUMMARY

Although the other reports in this series are organized differently, the summary presented here is responsive to the categories entitled:

Measurements

Engineering Practices (Standards)

New Applications of Technology

System Design Analysis

Software

Teleservices

Other

The order of presentation is not necessarily in order of importance. With the exception of the category entitled "New Applications of Technology," the recommendations incorporated in the summary are considered important steps which will aid the development of the CATV industry and result in customer-acceptable products and teleservices. New applications of technology are introduced because they hold the promise of solving some present technical problems in a different way with accompanying economic benefits.

These recommendations are based on the available literature and numerous conversations with individuals at all levels in various parts of the CATV industry, other industries, and government agencies.

The reader is referred to the individual reports associated with each topic. Each report also has a summary which provides the first level of detail in the discussion of the subject.

3.1. Measurements

3.1.1. Introduction

The development, installation, and operation of a telecommunication network cannot be divorced from

During the survey, a number of technical areas in which engineering practices or standards would help the CATV industry were observed. These are outlined in the next section although the list is not considered complete. Some of the applicable EIA standards are RS-252-A (1972), RS-240 (1961), RS-250-A (1967), RS-207 (1958), RS-341 (1967), RS-330 (1966), and RETMA REC-140 (1954).

3.2.2. Current Needs in CATV Standards

Alarm sensors, meter reading units, facsimile units, keyboards, etc. should have standardized interfaces so that subscriber terminal equipments have some common functional forms, some common interface connections, signal levels, signaling formats, and modulations. This will contribute to ease and convenience of use, reduce consumer education requirements, and allow for possible subscriber ownership of equipment.

Further, modular design of equipments and standardization of the modules would appear to be important in the development of subscriber terminals. Modular design will allow for expansion of the terminal through simple plug-in units that interface with the control modem in the subscriber's home or office (Wieder et al., 1973).

A standardization of terms and measurement techniques is needed. An example is signal-to-noise ratio, which is a

frequency used and inadequately defined term. Another example is third-order distortion. The standardization should be in line with that used in other fields of communication engineering. For the standards to be readily accepted, they must be advanced by the industry, perhaps through a professional society, such as the IEEE, or a trade association, such as the NCTA (Chadwick et al., 1973).

Standards on system equalization are needed to meet the increasing demands on cascadability of amplifiers. Closely related is the need to define and specify the overload levels of amplifiers. Acceptable levels of overload, in terms of noticeable distortion in the delivered signal, can and should be defined (Chadwick et al., 1973).

A consistent and universally accepted definition of cross modulation is required; test procedures for measuring cross modulation should also be standardized (Chadwick et al., 1973).

Current quality control and installation practices adequate for one-way distribution systems may not be acceptable for two-way transmissions. Pickup of spurious signals in some of the experimental two-way systems has been experienced as the result of inadequate quality control. How an improvement in this regard may be made to eliminate the associated problems should be experimentally studied and

engineering practices of installation should be developed (Chadwick et al., 1973).

The present monochrome and color standards for television use in this country (NTSC) and in the CCIR have been in existence for over 3 decades in the case of monochrome, and almost 2 decades in the case of color. A boundary condition accepted by the National Television System Committee in both cases was that the channel must be only 6 MHz wide. These standards were developed for broadcast applications and have been quite successful. There are at present over 64 million homes with television sets constructed for operation with the NTSC standards. It is recommended that these standards be reviewed in light of the specific needs of CATV systems, frame-grabbers, and the new technology of charge-coupled display devices (Chadwick et al., 1973; Smith et al., 1973).

The development of digital interface standards for CATV two-way systems becomes important as interconnection of systems grows and as the replication of individual systems in several locations occurs. Both hardware and software standards should be developed. The EIA RS-232-B standard for digital communications via the telephone system could serve as a model for the CATV industry. The CATV software standards would require additional research since this area

has not developed as far as the hardware standards area (Chadwick et al., 1973; McManamon, 1973).

The television signal at a CATV head-end must be distributed through the CATV system, with most of the distribution by cable. The signal quality of the signal received at the CATV head-end from a microwave circuit or satellite terminal would be expected to meet some minimum standards of performance for CATV distribution over cables with many amplifiers in cascade. Standards do not appear to exist for CATV distribution. To avoid future retrofits and to minimize compatibility problems of equipments and signals, interconnection transmission standards for video, data, and voice signals need to be developed (McManamon, 1973).

The potential exists for considerable near-future dependence on interconnection for development and growth of two-way services. Common carriers, specialized common carriers, and satellite systems quite likely will be involved in this growth process. Information about existing and planned networks, capacities, operating and design parameters, tariffs, computer-communication networks, and other relevant data for CATV operators, investors, and government officials is not available in any convenient form. In many cases this information is difficult to obtain in a timely manner. What appears necessary is an

information handbook on CATV interconnection background data (McManamon, 1973).

3.3. New Applications of Technology

3.3.1. Introduction

Telecommunications theory and technology has experienced substantial changes during the past 30 years. Further, some evidence exists to suggest that the rate of change is increasing. Each element of the CATV system has undergone such a technology experience. Methods of system design and the designs have changed. It is apparent that these changes will continue.

During the survey, numerous potential applications for new technology in CATV systems arose both in the literature and also among the authors. These are listed here more as a stimulus toward research and development efforts in these areas than as a complete list.

3.3.2. Subscriber Terminal

The design of a subscriber home terminal for two-way communications systems is an urgent need for the industry. This design should be compatible with the existing TV off-the-air reception, but should incorporate the necessary features for two-way digital communications with a variety of user response units ranging from simple keyboard units to

full interactive graphic terminals. Some indications are discussed (McManamon, 1973) which suggest that CATV systems must develop an aggregation of services available through a multipurpose terminal. Thus a video/voice/data terminal with memory appears to be needed.

Research to develop this home terminal should be undertaken considering the human factors in interfacing with the system, considering efficient utilization of the spectrum, and offering a modular design that can service a wide variety of subscriber needs. The present hybrid approach of using existing components such as the home TV receiver is not adequate (Wieder et al., 1973; Campbell, 1973).

Many proposed teleservices require the storage of a video frame at the television receiver. This device has come to be known as a frame-grabber. Technology for frame-grabbers which store the video signal in analog format is principally limited to video tape recorders modified for stop and idle capability, video disc recorders, and various types of vidicon storage tubes. New advances in charge-coupled device technology as well as other solid-state displays show promise that new devices will be added to the list in the near future. If the analog picture is sampled and quantized into a digital format, semiconductor memories and LSI technology could be used for storage of a frame.

This technology has not been brought to bear on development of economically feasible frame-grabbers for CATV

system subscriber terminals. Such a development effort should be undertaken in order to specify costs and capabilities which are realizable in the near future (Wieder et al., 1973).

3.3.3. Head-ends

It has been estimated that many of the existing systems do not have a design potential for more than 12 channels. Most systems operate with an inadequate head-end, and in order to meet the modest FCC standards, a large number of systems will have to make corrections. As systems strive to reach their design potential and head-ends become more fully loaded, these problems will worsen. There is a need for improvement and specifications (Smith et al., 1973).

Present use of computers in CATV systems, even pilot ones, is both modest and cautious. At present, an investment of roughly $70,000 (±$20,000) is involved in the addition of the computer to the head-end, but this is expected to decrease rapidly with time. In addition to using computers at the main head-end of a system, it can be contemplated that many computers will be used downstream of the head-end for carrying out line-conditioning, switching, etc. The difficulty appears to be little activity in this field by both computer technology workers and CATV system operators.

Two types of effort are appropriate here. The first would involve a cross-education process between the two technologies to identify needs and capabilities which are relevant to each. The second would involve some sample design efforts to identify the limitations of present general purpose computers and software in the CATV application (Campbell, 1973; Smith et al., 1973).

3.3.4. Transmission

Glass fiber waveguides utilizing optical sources and detectors show promise for use in lieu of coaxial cables and conventional electromagnetic sources. The remaining development tasks are economical as well as technical in nature. A cost analysis is lacking; in addition, such technical areas as coupling, fiber joining, space multiplexing, and dispersion need additional effort to fully exploit the evolving technology of fiber waveguides operating at optical frequencies (Chadwick et al., 1973).

Direct satellite-to-the-home television broadcast still faces technical limitations because of cost factors. Because of these limitations, CATV systems become one of a number of reception centers for satellite television distribution. In the next five years one-way and two-way services via satellite will be influenced strongly by the domestic satellite systems proposed and the ATS-F

educational television experiment. The Canadian Domestic Satellite ANIK I is operational, with ANIK II to be launched in 1973. Up to twelve television channels apparently can be leased to U.S. companies for one to two years. These channels could have an impact on CATV television distribution through interconnection by providing long distance facilities during 1973 without large terrestrial microwave network construction. The next planned NASA satellite launch associated with CATV systems will be the ATS-F Educational Television Broadcast one-year experiment in the Rocky Mountain area scheduled for the spring of 1974.

The Canadian Technology Satellite to be launched by NASA in 1975 will investigate the feasibility of direct satellite data, voice, and television broadcast to receive-only terminals in the 10 GHz band. For future development, it is recommended that a program be developed to investigate the feasibility of inexpensive earth terminals operating in frequency bands above 10 GHz. Operation at these frequencies is not faced with as many international and national restrictions, particularly relative to satellite radiated power flux density (McManamon, 1973).

In the FDM/FM microwave relay and satellite transmissions, wide-index frequency modulation is used because of the unavailability of linear microwave final power amplifiers. The consequence is the use of bandwidths

on the order of 25 MHz to 35 MHz to transmit a 6 MHz television signal. While FM processing gain is obtained so that lower powers can be used for acceptable demodulation signal-to-noise ratios, the demand for increased spectrum efficiency suggests that recent developments in the design of linear microwave power amplifiers should be exploited. This development could have an impact in replacing wide-bandwidth, high index FDM/FM with narrow-bandwidth SSB/AM (McManamon, 1973).

3.3.5. Digital Techniques and Picture Coding

Current research in video picture coding of broadcast quality signals has established the feasibility of a 4.1×10^6 bps digital data rate per video channel when groups of 12 to 15 black and white Picturephone* channels are multiplexed. With about 19 to 20 dB signal-to-noise ratios, eight level coherent PSK modulation ideally could be used to transmit this data rate in a bandwidth between 1.4 MHz and 2.8 MHz at a bit error rate of 1×10^{-6}. This indicates the potential for transmission of more than one digital television channel in the present 6 MHz analog channel bandwidth. Further, a single cable ideally may be able to carry up to 80 digital television channels.

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These signal-to-noise ratios are over 20 dB below that presently required in the CATV interconnection and trunk circuits. A trade-off may exist in the required number of amplifiers versus the required digital equipment. The latter would be substantial, though, with present technology. Investigation of digital picture coding and transmission techniques is recommended for entertainment television signals and other CATV signals (McManamon, 1973; Chadwick and McManamon, 1973).

The length of present CATV trunks is limited by two effects: the build-up of thermal noise in the cascaded system and intermodulation noise due to inadequate dynamic range in trunk amplifiers. At present, the only ways to increase system length and performance are to use larger and more expensive cables and more sophisticated and more expensive amplifiers or to use sub-baud trunking. The fundamental reason for this is that the present TV video signal was not designed to be transmitted over a cascaded cable system. Digital techniques have the advantage of being able to operate at greatly reduced signal levels, which eases the requirements on system dynamic range and on the channel signal-to-noise ratio at which the system must operate. A simplified cost analysis (Chadwick, 1973; Chadwick and McManamon, 1973) indicates possible reductions in cable cost when digital transmission is used. In

addition, it is likely that longer systems can be realized when the system uses digital transmission. A more complete study of the technical and economic possibilities of using digital transmission in the downstream trunks is needed.

Digital techniques also have numerous advantages for the upstream signals in two-way CATV systems. In addition to possible economic advantages pointed out above, digital signals offer greater flexibility for multiplexing many signals together. Since two-way CATV systems are just now coming into existence, signal design philosophies are not rigidly fixed as is the case for conventional analog television. It is important that the industry not become locked into a design that is inflexible for future requirements. Work should be undertaken to point out possible technical and economic advantages of different digital encoding, digital signaling, and multiple-access techniques with application to two-way CATV systems (Chadwick et al., 1973; McManamon, 1973; Chadwick and McManamon, 1973).

3.3.6. Computer Communications

Another area for the application of new technology is the design of a special computer system for two-way broadband communications systems. This design would be optimized for real-time communications-oriented applications. This design should use the latest modular

architecture of the polysystem concept and the large scale integration hardware concepts for economical considerations. Specific software for two-way communications must be developed, including a CATV two-way communications oriented compiler or user language. An important aspect is the current technological limitation on the number of terminals a time-share computer can service simultaneously (Smith et al., 1973).

Digital data networks may provide a suitable short term interconnection network. Operation with computer-communication networks would be feasible. The present ARPA computer network could be used for demonstration of feasibility and potential. Interaction between CATV systems and computer-communications networks could have the potential of creating a new source of one-way animated graphics and two-way interactive programs for CATV system use (McManamon, 1973).

3.4. System Design Analysis

3.4.1. Introduction

In the development of equipment for telecommunication system application, the designer is usually faced with a number of critical decisions. These decisions usually depend on the specific system application and the associated constraints on system components. The recommendations of

the following two sections concern design of the system and components as viewed from the system viewpoint. In section 3.4.2, the overall system is considered, whereas in 3.4.3, system elements are viewed within the context of the system.

3.4.2. Systems

The development of many proposed services has the long-term potential of needing hundreds of television channels within communities as few as 30,000 subscribers. A queueing model presented by McManamon (1973) illustrates the reasons for the large number of channels required. Extended queueing analysis is needed in order to assure that systems implemented will have the capacity to serve satisfactorily a large number of subscribers. With such a demand for television channels in a CATV system, the need for extensive interconnection regionally or nationally may not be as great as some forecasts suggest.

On the other hand, many services proposed (including partial substitution of telecommunications for travel) may require extensive regional and national interconnection in order to be implemented in the near future. The systems will necessitate large computer systems and software development. Once established and proven, the services would begin to be implemented locally.

The current problem is the lack of sufficiently complete system designs, cost estimates, and performance evaluations

for implementation of most proposed two-way services. Certain parts of each system would have to be implemented in order to develop realistic engineering-economic data for performance analysis. System designs would not have to be developed for all services immediately. It would be a contribution to work out the details of even one of the proposed services. System designs published by others (Mason, 1972; Baer, 1971) provide good starting points (McManamon, 1973; Campbell, 1973).

Network design for rural subscribers faces more difficult problems in transmission distance and cascading of amplifiers. An investigation of the potential use for digital video techniques should be undertaken (McManamon, 1973; Chadwick et al., 1973).

3.4.3. System Elements

Frequency allocations for broadband cable are not yet standardized although special committees are working on the problem. Allocations designed to obtain the fullest use of the spectrum, but which will minimize signal degradation due to cross-modulation, intermodulation products, local oscillator interference, etc., should be investigated (Wieder, 1973; Chadwick et al., 1973).

Effort should be directed to the feasibility of reducing the dynamic range problems. Pre-emphasis and companding

techniques should be studied for application to CATV transmission (Chadwick et al., 1973).

The amplifier is an essential and important component in any of the cable systems. Its characteristics will certainly affect various aspects of the system performance. Therefore, optimization techniques in the sense of maximizing power gain, bandwidth, dynamic range, or combinations of these should be studied (Chadwick et al., 1973).

Co-channel interference is a fact for the single cable bidirectional system. As such, it will degrade the quality of the received signal. This problem should be studied from the overall system viewpoint. If digital techniques are to be applied for the future cable system, an optimal approach may be developed to minimize the signal-to-interference ratio under different conditions (Wieder et al., 1973; Chadwick et al., 1973).

Given a cable network configuration with a specified number of components, interconnections, and a certain number of subscribers, a detailed analysis of the signal quality at the subscriber's terminal should be made so that a synthesis technique may be devised. The synthesis work may be carried out from the viewpoint of determining a "best" network system in order to meet a specified signal quality at the home terminal (Chadwick et al., 1973).

Designs of crossover filters used to separate upstream and downstream transmissions should be improved to insure that imperfections from group delay distortion and insertion loss may be brought to more tolerable levels (Chadwick et al., 1973).

Design of cable configurations using the existing knowledge of network topology developed for the circuit theory is another aspect deserving attention. Results from studies in this regard may be useful for designing good network systems from economic or other considerations (Chadwick et al., 1973).

The A.T.&T. projections for their voice and data common carrier network growth to meet 1980 demands is over 3,000,000 new channel miles. The present 1,180,000 channel mile microwave network is only one-third of the projected 1980 network. Two-thirds of the required new network must be constructed. Projections for terrestrial specialized data common carriers suggest little if any excess capacity for CATV interconnection. The large bandwidth radio and waveguide transmission systems are largely in the research and development cycle.

These projections suggest that substantial CATV system interconnection growth will depend on availability of U.S. Domestic Satellite systems. The Canadian and U.S. Domestic Satellite systems as launched or originally proposed total

over 624 transponders in synchronous orbit. Each transponder can relay one color television broadcast quality signal. These systems generally use the 4 GHz and 6 GHz terrestrial common carrier transmission bands and have to operate at reduced radiated power levels to avoid interference with the aforementioned terrestrial microwave network. The resulting effect is the high cost of transmit/receive and receive-only ground terminals ($200,000 and $100,000, respectively). Further, the ground terminals must be located away from existing microwave links. Consequently, new microwave links will be needed to interconnect the earth terminals with the CATV systems. The impact of these costs for satellite terminals in association with the U.S. Domestic Satellite systems and CATV system use has not been explored (McManamon, 1973).

3.5. Software

Software is likely to be as critical as terminal hardware in determining the cost of two-way subscriber services. One can identify four levels of software that need to be provided in a functioning system. Level 0 (monitor software) largely exists; level 1 (executive software) exists for a time-sharing system but by no means can be expected to suffice for CATV systems. Level 2 (problem oriented languages) does not exist at all except

for the possibility of some computer aided instruction (CAI) course construction programs. Finally, level 3 (applications software) does exist in some sense (Smith et al., 1973).

The design of real time software for controlling and servicing a two-way communications system has many design trade-offs and many unknowns. Some of the most critical of these software problems are:

a. Dynamic, real-time priority allocation is required in a two-way communication system to make effective use of the computer system and to process subscriber requests in some reasonable response time.

b. Time-critical processing algorithms for two-way systems is important.

c. Storage and file allocation and control is a critical factor in a system offering two-way communications to subscribers.

All of these areas require additional research to fully realize the potential of a computer controlled two-way communications system (Campbell, 1973).

3.6. Teleservices

Numerous authors present lists of services such as table 1 which are potentially possible using the cable

transmission bandwidths available in some present and proposed two-way CATV systems.

The CATV industry and manufacturers appear to face a development problem in which a CATV system is necessary to test the marketability of proposed teleservices. A substantial capital investment must be made in Top-100 markets to obtain a CATV system. Further, industries related only obliquely to the CATV industry (banking, merchandising, etc.) must make substantial changes in organization and procedures, with corresponding capital investments, to provide services on cable.

The danger lies in the finite probability of non-acceptance of the service by customers. As an example, consider the Bank of Delaware, in Wilmington, pilot program and automatic billing of utility services (Bunting, 1972). The Bank of Delaware pilot program involved Touch-Tone* telephones and plastic identification cards for merchandising. Full details of each transaction were automatically printed in both statements and sent to the store and customer. The pilot program was abandoned - for the most part because consumers didn't seem to want their affairs conducted in this way.

Automatic billing of utility services have not been accepted very well either. "In Philadelphia, for example, something like 2/10 of 1 percent of the customers of

Philadelphia Electric Co. signed up with the banks of that city for automatic billing" (Business Week, 1972). These observations lead to two inter-related major issues.

Many proposed services could be implemented individually through regional interconnection using the existing telephone system. Commercially available terminals can be interconnected through Data Access Arrangements. The Touch-Tone* telephone has numerous potential applications which provide many of the proposed services as described by Martin (1971). A number of unanswered questions arise:

a) Which of the services proposed are better suited to the switched telephone network?

b) Why are these services not being marketed at the present time, using existing terminals, computers, and the telephone system?

c) What would be the effect on top 100 market penetration by CATV systems if common carrier competition developed for some of the proposed CATV system services?

3.7. Other

It is sometimes predicted that we are moving towards the era of the insular home, a self-sufficient electronic

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island. In that event the question of privacy will loom evermore important. A broadband communications channel into each home makes possible several categories of invasion of privacy:

(1) surveillance (the observation or monitoring for the purpose of obtaining information about movements, activities, habits of a subject)

(2) aggregation (the accumulation in the central file or in disbursed files of information associated with a single subject)

(3) disclosure (the improper dissemination of information within an information system)

(4) intrusion (unwarranted entry of information via electronic avenues into a place of privacy).

The problem of privacy (and security) and the computer has been examined seriously by such organizations as the Defense Department. It must be recognized that in all probability 100 percent security can never be gained. This problem must be given serious attention in the development and growth of CATV systems (Smith et al., 1973).

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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report summarizes the results of a survey of the CATV industry and related technological industries. The following six reports (OTR 73-13, Volumes 2 to 7) deal with the survey results in detail. The survey identifies some of the important technical factors which need to be considered in order that a transition from the technical state of today's cable television and services to new teleservices may be brought about.

The relationship between systems and teleservices is explored. Technical summaries are presented in the areas of measurements, standards or engineering practices; new applications of technology, system design analysis, software, and teleservices.

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