An Evolutionary Approach to the Development of Two-Way Cable Technology Communication

JAMES B. WRIGHT
Rockford Cablevision, Inc.

MARTIN P. BLOCK
Michigan State University

D. STEVENS McVOY
Broadband Technologies, Inc.

While community antenna television (CATV) has continued a pattern of steady growth, the "blue-sky" promises of a cable revolution have yet to be realized. Despite the Federal Communications Commission rule requiring technical capacity for nonvoice return communication, two-way CATV has really not progressed much beyond the experimental stage. A combination of four factors are responsible for the slow development. First is the lack of credibility in the cable industry surrounding two-way CATV, due largely to some early over-zealous speculation and over-selling of the two-way CATV concept before the technology could deliver. Second is the inability of two-way CATV to attract adequate financial resources, creating the familiar "chicken or egg" problem. That is, without the financial support the technology cannot be developed, and without demonstrated technological promise the financial support cannot be generated. Other conditions contributing to the financial problem include the recent recession, high interest rates, and industry overexpansion. Third is restrictive governmental regulation which requires performance levels and services that contribute to higher operating costs and at the same time limits the entertainment fare, which reduces the potential revenue. The profit squeeze would limit interest in developing new services, as well as making the industry less attractive for investment purposes. Fourth are technical problems in the development of two-way CATV such as radio frequency interference and the design of a relatively inexpensive home terminal.

While the outlook for two-way CATV does not seem particularly bright, a few recent events keep the promise alive. The National Science Foundation has made a large funding commitment to experiments in public service applications of the two-way technology. This will advance both the technology and our knowledge of potential applications. Secondly, the per-program pay television system in Columbus, Ohio has been a commercial success. In development of the Columbus system a number of technical and cost problems have been solved. These events, which will be discussed here in some detail, provide solid evidence that two-way CATV can be developed despite the apparent problems.

To assure this development, a systematic approach is needed which carefully times and integrates the technical capability with economically viable communication applications on a step-by-step evolutionary basis. This paper is an attempt to provide an outline of an evolutionary process which is believed to be feasible. It will begin with a description of the particular communication capabilities and potentials of a CATV system.

Communication Capabilities of CATV

A CATV system, by its physical nature, is most efficiently used as a means of disseminating information from a single point, or source, to a large number of points, or users; and conversely it may also be efficiently used as a means of acquiring information from a large number of remote sources and transporting it back to a single point. A CATV system is used least efficiently in point-to-point communications. It is because of this unique characteristic of a CATV system that most discussion of two-way CATV is in terms of a digital return system generated by push-button response pads.

Despite the popular characterization of CATV as the television of abundance, there is a very real limit to the available bandwidth in a cable system. The use of any available frequency must be considered in terms of both opportunity cost and the cost of additional equipment necessary to support it. This demands careful planning and spectrum management.

A typical CATV system resembles a tree, with a network of trunk cable and trunk amplifiers delivering signals from the headend or transmission center to bridger amplifiers. These amplifiers then transfer the signal to a system of feeder cable and feeder amplifiers. The feeder system delivers the signal to the tap-off units, and then by service drops into

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the subscriber's home. The return problem of noise and interference is most severe in the feeder and drop portion of the cable system. Here there are many thousands of individual fittings and every customer service drop is a potential "interference-antenna." It is the interference problem in the feeder portion of the cable system that makes using it for return video signals impractical. Return video signal service is possible in the trunk portion of the system, and data return signals are practical for the feeder portion of the system. An aural return signal service via cable would seem to be of limited value because of the existing service provided by the telephone company. This leaves the most practical design for the upstream portion of a two-way CATV system as video and high-speed data by trunk cable, and data only by the return feeder cable.

The next consideration is in the allocation of the limited bandwidth in the cable system to forward and return channels. It should be obvious that increases in bandwidth allocated to the return signals cause decreases in the bandwidth available for forward video signals. Fortunately data signals usually require considerably less bandwidth than do video signals, and data signals can be both time and frequency multiplexed, as well as "area" multiplexed which will be described later. Probably the best allocation would be approximately 250 MHz for forward service use channels, and only about 25 MHz for the return service. More details about the basic two-way system in each stage of its evolution will be provided later.

Applications of Two-Way CATV

One of the greatest obstacles to the continued development of two-way CATV technology has been the attraction of necessary investment capital. Investors do not see sufficient return from any application of the current technology to justify the risk. The exploitation of two-way CATV applications has failed because each application has been considered in isolation, without a convergence of multiple applications for cost-sharing the two-way plant. And, further the two-way technology has never evolved as a synthesis of practical need and cost-efficient technology. Two-way has been considered in terms of some end-state of both technology and application. The step-at-a-time approach has not been followed.

Unlike other communication media, two-way CATV has captured the interest of the public sector early in the developmental stages. Whatever the future of two-way communication, there is almost no doubt that the public sector will play a prominent role, and that two-way CATV will involve applications from both the public and private sectors.

A wide variety of public sector applications for the two-way CATV technology have been developed through the National Science Foundation research. The MSU team has developed applications which include a program to diagnose developmental delays in children under age five in the home, a large scale cable information and referral service based upon a series of interactive television vignettes describing various social services and programs within the community, providing an extension and supplement to elementary science education through teleconferencing and computer-aided instruction, and a series of legal communication applications including an automated legal library, publication of court-generated information, the taking of depositions, and the use of the system as a research tool to evaluate the effect of television advertising on children. Other applications have been suggested by other research teams.

Private sector applications of two-way CATV technology have lagged behind the public sector applications because of limited research and development money in the relatively-small cable industry. Further, the industry has been preoccupied with more immediately-profitable commercial applications such as pay channels. The private sector application receiving the most attention is per-program pay TV, with the previously discussed Telecinema system the only large scale operational example. Beyond per-program pay TV, there are few demonstrations of any private sector applications of two-way technology. For the future, other private sector applications may include marketing and advertising research, in-home shopping, and in-home monitoring and surveillance services. Among the suggested marketing and advertising research applications are television audience measurement, television advertising copy pre-testing and post-testing, television program pilot testing, package design tests, advertising concept tests, product purchase behavior measurement, and various other questionnaire-oriented research including awareness and preference measurement. Among the in-home shopping applications are electronic supermarkets and catalogs using special dedicated channels and interactive advertising. Among the in-home monitoring and surveillance applications are monitoring heat and smoke detectors, intrusion alarms, tamper alarms, power load management and utility metering; and, metering applications involve the remote reading of utility meters with the capability of charging differential rates depending upon the time-of-day, and the ability to turn off various in-home applicances to reduce the load in the event of an emergency. Further in the future are other applications such as electronic mail delivery, electronic or automated newspapers, and the electronic public forum concept.

While the list of suggested applications for two-way CATV can be greatly expanded beyond the general categories mentioned here, such lists almost always consider two-way CATV technology as a fully developed monolith. Rarely is two-way CATV technology considered as an evolutionary process, with some applications preceding others as the technology and demand develops. It should be obvious that some applications of two-way CATV, such as per-program pay TV, are possible given the state of the technology today, and other more complex applications such as power load management require continued technological development.

In order to simplify the relationship between the technological evolution of two-way CATV and the applications, a classification scheme of six categories will be used. Ignoring all applications which primarily involve communication in an institutional framework, such as high speed data communication between banks or upstream video transmission from city hall to the cable transmission center, and concentrating on applications involving communication with only digital return from homes, the classification scheme includes the four private sector applications already discussed--pay entertainment, shopping services, marketing research, and monitoring services--plus categories in education and community information. The education category includes the in-service training applications in an in-home setting along with various adult education applications. The community information category includes the electronic mail delivery application, automated newspapers and related services, the public forum concept, and the social service information and referral system. The next task is to consider the evolutionary steps in the development of two-way CATV technology.

The First Generation

The first generation in the proposed model for two-way CATV system development was designed for a per-program pay TV system in Columbus, Ohio, and represents the important first step in the evolutionary process of two-way CATV technology. The Telecinema per-program pay TV system has been in operation for nearly four years. The Telecinema system involves a home terminal which costs approximately thirty dollars, and allows four channels of pay TV programming. The subscriber selects the appropriate channel, and is then billed only for the programs that are watched. This method of pay TV is contrasted with per channel pay TV where the subscriber pays a flat monthly fee for unlimited viewing.

A typical pattern for per-channel pay TV system is very high initial growth, probably around forty percent, followed by a drop to around 25 percent after the first few months of operation. Part of the explanation for this "churn" is the fact that people use only a small portion of the entire package of programs that is available, but feel they are paying for all of it--a sense that they are overpaying in relation to their usage.

The Telecinema per-program system was tried first by charging subscribers only for the movies that were watched. Penetration was eighty percent and average monthly revenues were about four dollars, which was not enough to cover the costs of both the movies and the two-way system. In 1974, a three dollar maintenance fee was added. This caused the penetration to drop from eighty percent to forty percent, but the subscribers who dropped the service were those who did not watch many movies. Revenue increased to eight dollars per month among the remaining forty percent penetration.

In December of 1975 Telecinema began experimenting with other forms of programming in addition to the core of Hollywood films. Adult films, children's films, sports events, nightclub performances and foreign films have been added. Average revenue has now increased to eleven dollars per month, and with increased experience in programming and advertising Telecinema is now predicting average monthly revenues of fifteen dollars per month within the next two or three years.

The implications for program producers are obvious, especially when related technology such as satellite program distribution is considered. The Telecinema system with over 5000 subscribers, is now the only operating per-program pay TV system in the United States. The system was designed to solve the early technical problems found when attempting to use interrogation-response type terminals in CATV applications--the high cost of the terminals and RF interference. Early cost estimates for in-home terminals ranged from $300 to $1,000, which is obviously too high to permit profitable operation. System maintenance costs, because of signal intrusion, were also estimated to be prohibitively high.

In order for two-way CATV to become economically feasible, it was necessary to design a system around a reliable terminal that would cost approximately $50, and be part of a system that can be reasonably maintained. The solution was suggested after consideration of the types of multiplexing available for the return data signal generated by the in-home terminals. Time division multiplexing (TDM) offers the advantage of sharing a single frequency for all the terminals, but can easily be jammed by one malfunctioning terminal. The source of the trouble is very difficult to find. Frequency division multiplexing (FDM) solves the problem of terminal jamming, but if very many terminals are to be used, too much spectrum space is consumed. The solution is a combination FDM/TDM system which allows the "area" multiplexing. It consists of the simultaneous transmission of groups of 100 frequency multiplexed terminals at different time intervals.

Area multiplexing is accomplished through the use of digitally controlled code operated switches (COS). Each COS consists of band-splitting filters which separate the downstream (50 to 300 MHz) frequencies from the upstream (5 to 30 MHz) frequencies. Downstream signals pass through the COS continuously without interruption, while the upstream frequencies are either passed or blocked as directed by a digital signal generated by minicomputer. This now allows an entire system of in-home terminals to be scanned in groups of 100 by activating and deactivating appropriate COSs. Placing a primary COS at each trunk, and a secondary COS at each bridger amplifier makes possible the scan of an entire feeder branch which would normally consist of between 100 and 200 homes. This design can be seen in figure 1.

The use of the COS system allows for a much less expensive terminal than a typical interrogation-response terminal because a great deal of circuity can be eliminated, including the RF receiver, decoder and address-recognition circuitry. A simple FDM terminal requires only a data encoder and RF transmitter circuity, which with the area multiplexing affected by the COS network is all that is required. The home terminal consists of a modified CATV converter which costs approximately $40. The modification consists of the addition of a circuitry board containing only an FSK transmitter and data encoding circuitry, costing an additional $20. The terminal transmitter is assigned a discrete frequency in its own COS area, and is transmitting all of the time. Each terminal transmits a 16-bit data word which indicates the status of the converter including the channel selected, whether the subscriber's television set is off or on, and whether the security key on the converter is on or off.

A General Automation SPC 16 minicomputer manages the entire scanning operation through the use of special interfaces which control a COS addresser and RF receiver. The minicomputer operating in real time, routinely scans the system collecting data and generates viewing reports. Additional routines are available for terminal installation and system maintenance. Batch programs generate billing and other reports required by the cable operator.

System maintenance is easily accomplished through the combined use of the minicomputer and the COS network to isolate interference and other problems. End of line oscillators (ELO) at the end of each feeder line, add a unique carrier frequency for easy identification and help in balancing the system. The Columbus system is maintained in this manner using one technician for the approximately 200 miles of plant.

The first generation two-way CATV system is primarily designed as a per program entertainment system. It does not allow for any interactive response, but only relatively simple monitoring of the status of the CATV converter attached to the television set. The only other feasible application for first generation technology is simple television audience measurement, since the system can be scanned at more frequent intervals than commercially available mechanical diary services. The first generation, however, has clearly demonstrated both the technical and commercial viability of this technology, and paves the way for new generations.

The Second Generation

The second generation system is designed for the MSU experiments being conducted in Rockford, Illinois with National Science Foundation funding. The National Science Foundation awarded seven planning grants in 1974 designed to develop the potential of two-way CATV emphasizing applications in the public sector. In 1975 NSF funded research based on designs developed by three of the original grantees: the Alternate Media Center at New York University, Rand Corporation, and Michigan State University (MSU).

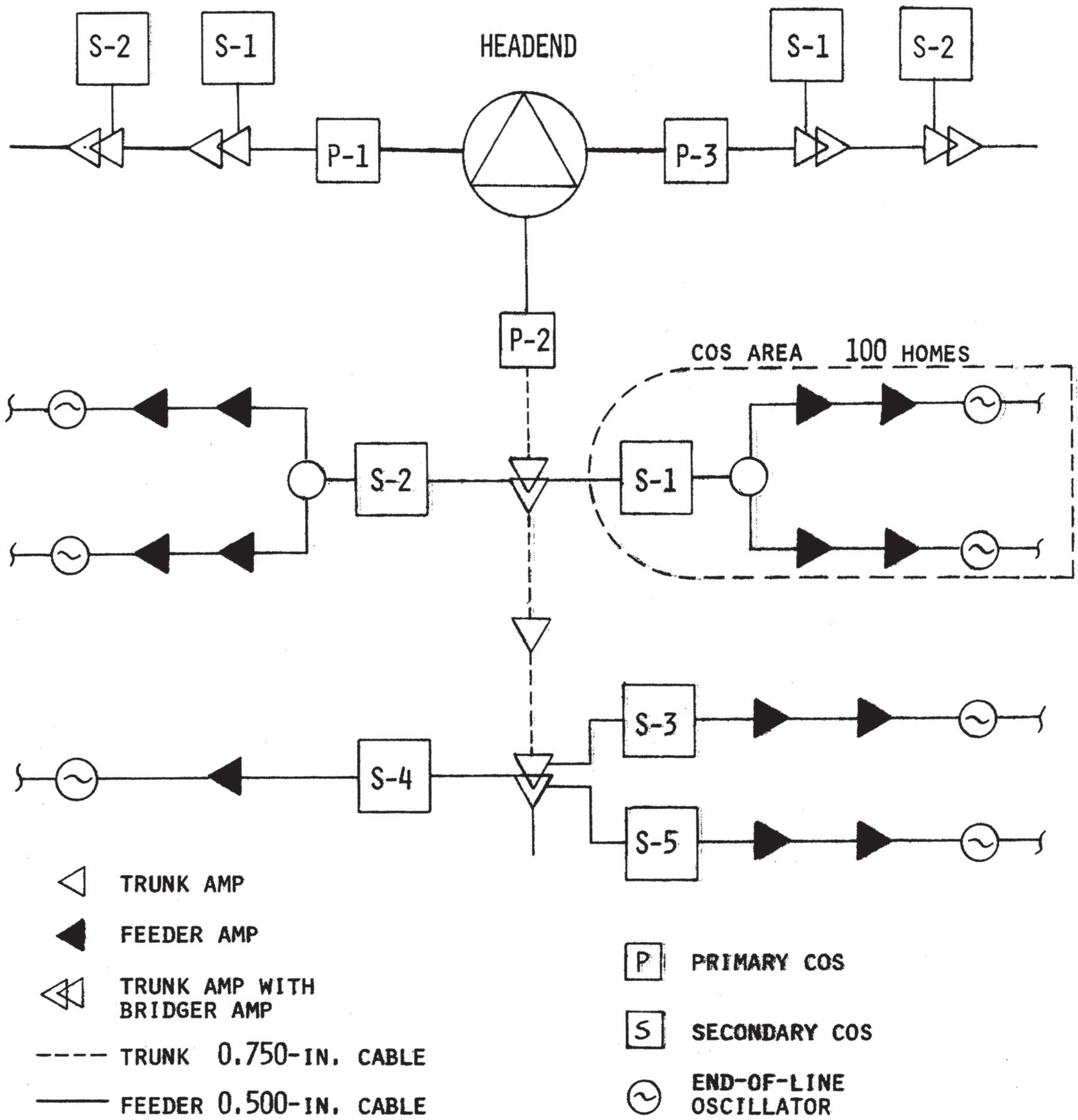
The MSU team is conducting an experiment using two-way CATV in Rockford, Illinois. The initial application involves the in-service training of firefighters, with an additional application in association with the University of Michigan involving the in-service training of elementary and secondary school teachers. The experiments represent a substantial investment of federal funds, with the MSU, University of Michigan projects costing over three-quarters of a million alone. The entire NSF investment is nearly three million dollars.

Approximately one-third of the MSU project investment has involved the development of the necessary two-way CATV hardware and software required for the project. Additional investment has been made by Rockford Cablevision in constructing the necessary two-way plant in the city. The two-way CATV facility in Rockford, along with the nationally projectable socio-economic and demographic mix of households available in the community, make Rockford a natural experimental site for experiments in two-way CATV.

The major difference between the first generation (Columbus) and the second generation (Rockford) is the addition of an interactive response capability at the terminal. Rather than providing only monitoring capability of the status of a channel converter, the channel converter selection buttons can be depressed to transmit a return signal. This requires relatively minor modification of the first generation terminal, including addition of interactive channels and a transmit button. The additional channels allow the terminal to function as a converter as well as an interactive terminal. The transmit button, along with a

FIGURE 1

First Generation: Area Multiplexing



timed LED display, insure the subscriber responding only when desired and at intervals longer than the minimum scan. The second generation terminal requires a push-button type converter, which is not necessary in the first generation.

The transportation system of the COS network and ELOs remains the same as before. The major difference in the second generation is in the minicomputer system. Since more processing is necessary with the possibility of a response in addition to the monitoring already required, the minicomputer system needs to be augmented with extended core memory and sufficient disk storage to accomodate interaction. The primary advance to the second generation is not hardware, but rather computer software.

The minicomputer software necessary to support second generation must not only perform the basic system scan routine and system maintenance, but it must also process any response data in real time. The MSU team has developed a specialized minicomputer language designed to coordinate downstream video signals with the appropriate interactive response making it relatively easy for a non-computer oriented individual to make use of the two-way system. The specialized minicomputer language was designed for the in-service training projects in Rockford, but could be modified for other applications.

The coordination of downstream video signals and the interactive response signals imply control of headend video equipment by the minicomputer system. This is accomplished by using computer-controllable character generation equipment, standard SMPTE time code interfacing with any video tape equipment, and standard process control input/output signals and relays to control the necessary video equipment. This makes possible minicomputer control of the entire two-way system. The second generation system is shown in figure 2.

The second generation terminal costs more than the first generation because of the need for a more sophisticated basic converter, and a small amount of additional circuitry and terminal modification. Depending on the quantity, second generation terminal costs range from $100 to $150.[1]

The second generation interactive response capability opens many new application areas for two-way CATV technology. In addition to the in-service training applications described above, which this generation was designed to support, many applications are of interest to both public and private sectors. Applications of primary interest in the public sector include the public forum and the social service information and referral system. The second generation allows for upstream transmission of digital signals, but it does not allow the subscriber to receive individualized information, that is downstream information must be shared when transmitted on the same channel. It is not practical to allow subscribers to have the downstream portion of any interactive programming "on-demand," rather such programming would be distributed on a pre-arranged schedule. This is an important limita- of the second generation technology.

Private sector applications include in-home shopping services such as interactive advertising and a crude form of electronic catalog that would be operating on a fixed schedule. Marketing research applications can be greatly expanded because of the addition of active response. Multiple choice questions can be asked and special video material shown to respondents in their own homes.

The capital cost of the first generation of two-way service is accommodated nicely by the per-program pay TV revenue. The incremental cost of the second generation, e.g., a more sophisticated terminal and greater computer capacity may be in the range of $20 to $30 per household or drop. Educational programs (public schools, public safety) which lease the service on a regular basis will cover a portion of that cost. Market research, direct selling and alarm systems should cover the remainder.[2] Thus far we have achieved or projected achievement of a substantial portion of the "blue sky" of the early 1970s. However, monitoring applications in the second generation must be limited to simple closure switches, such as a relay signal from a smoke or heat detector because only a few data bits are available in the terminal.

Partially because of the limitation of second generation equipment in monitoring applications, the third generation is being developed. The immediate advantage of third generation two-way CATV technology is the ability to monitor activity in the home requiring more complex code than a single bit.

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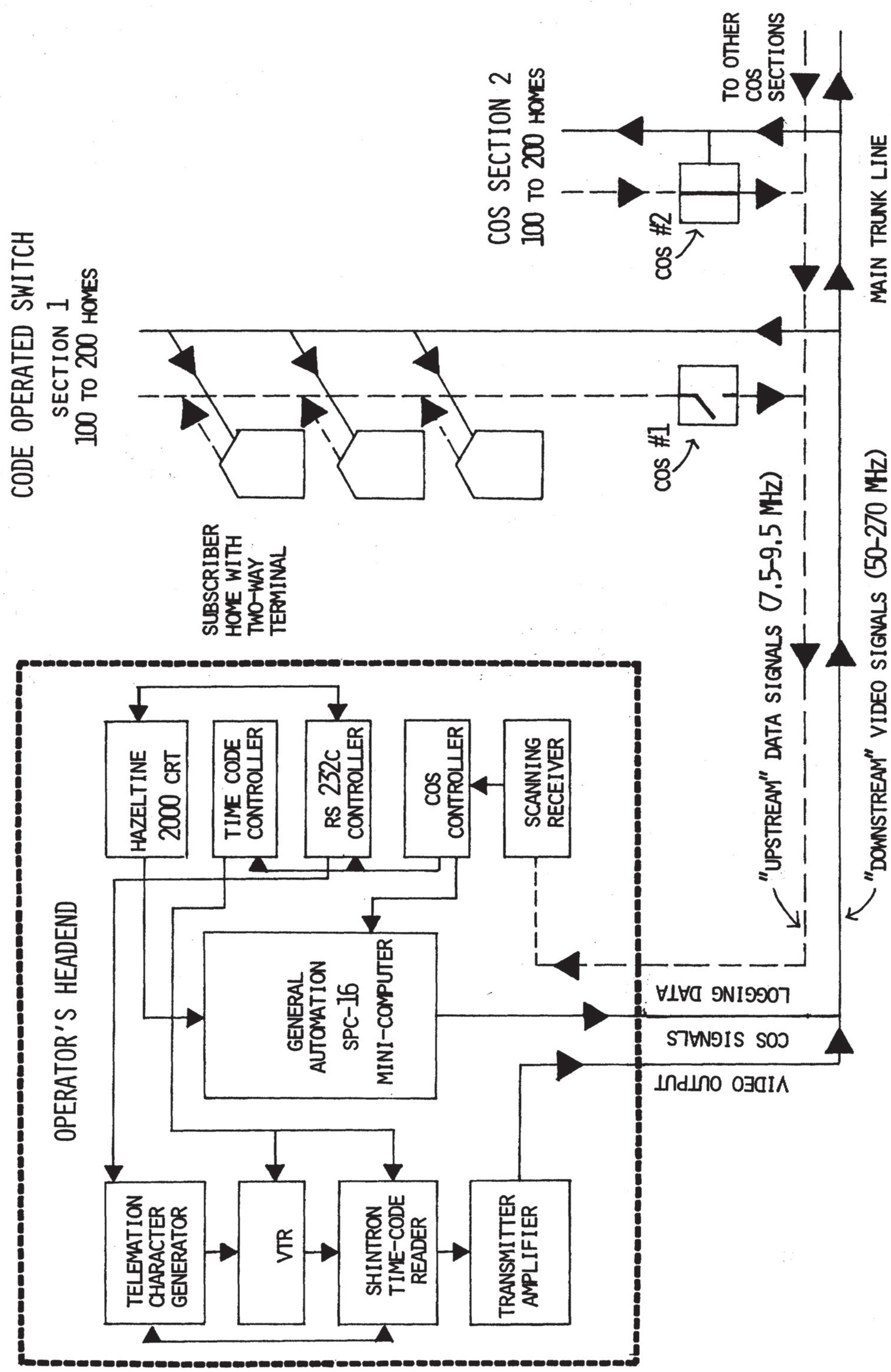
[1]Without the channel converter, the cost of the unit would be reduced by approximately $75. The stripped-down terminal device would provide only interactive response generated from a simplified push-button pad, perhaps only four buttons, but would not provide any monitoring of channel converter status. This would limit application of the system to interactive response, making per-program entertainment difficult.

[2]The huge advantage of smoke detectors which communicate directly to the fire department should be noted. When the household is occupied, the simple alarm can save lives and property, but the property is protected only during occupancy. With a communicator linkage to the fire service, the property is protected at all times.

FIGURE 2

Second Generation: Interactive Responses



The Third Generation

A necessary part of any two-way CATV power load management system is the ability to monitor utility meters. While transmitting utility meter information through the upstream communication system represents no technical problem, assuming the 16-bit data format, the scan must be designed to prevent the reading of utility meters from occupying the entire system. The problem for terminal design is to provide 16-bit data words recognizable by the minicomputer as either utility meter information, interactive response, or channel status. The terminal itself would be required to swap channel status and utility meter information to make possible simultaneous per-program pay TV and power load management applications.

The only practical solution to the data formatting problem is the addition of a microprocessor chip to the terminal. Microprocessors, such as the RCA 1800 COSMAC series, would add approximately $20 to the cost of the second generation terminal. Adding a ROM to store program instructions would allow microprocessor to accumulate utility meter data and format the 16-bit transmission word at the appropriate times. The third generation terminal is currently being developed. A working diagram is shown in figure 3.

The addition of the microprocessor to the terminal provides flexibility to most second generation applications. The ability to format the 16-bit transmission word within the terminal makes possible more complex data to be transmitted from the terminal than simple multiple choice selections. In the in-home shopping application, more complex information such as color, size or credit card numbers could be quickly entered through the keyboard, and then transmitted all at once rather than digit by digit. The marketing research and educational applications would also benefit from the increased input flexibility by being able to accept input data more complex than a single digit.

Another improvement is terminal technology is necessary at this step before moving ahead to the fourth generation. To improve control and security of the system, it is desirable to move the essential electronics out of the TV control terminal to a central location. This shift, the third-and-a-half generation, does not add anything in terms of potential applications, but rather provides more efficient operation because of increased maintenance convenience and terminal security. The latter is of critical importance, particularly in the utility metering applications, where thefts of service of staggering magnitude have recently been discovered.

The Fourth Generation and Beyond

The evolutionary steps beyond the third generation are not as clear as the first steps because the associated electronics and information processing technology itself are continually evolving. The next step will no doubt be the addition of low cost memory storage in either the terminal itself, or in a COS. This will make possible the transmission of time-compressed digital signals to a memory in a specific location such as an individual terminal.

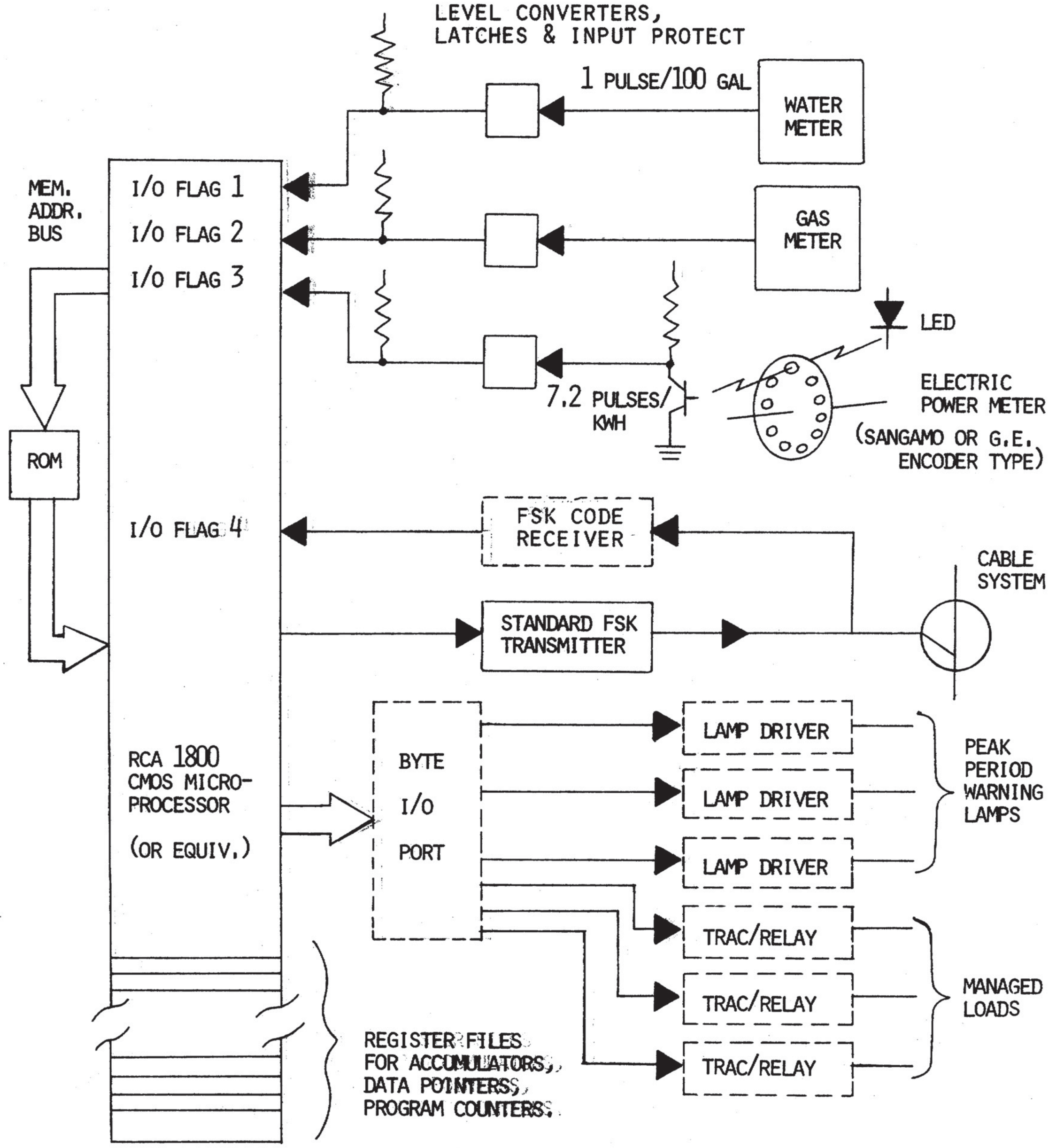
The addition of the microprocessor chip to the terminal also makes possible the decoding of downstream information with the addition of a RF receiver to the terminal. While additional signal decoding and character generation circuitry would also be required, it is technically possible to allow selection of portions of downstream data signals using keying or addressing scheme. If an entire downstream channel were devoted to digital information then it would be possible to "page" a portion of that data stream for local display on the home television set. This makes possible electronic automated newspapers which the subscriber can page through on demand. One video channel could easily accomodate the equivalent of 1,000 pages. The news could be computer refreshed and controlled. Another application is the delivery of second class mail and on demand catalogs. The limitation are restriction to digital information. The information is always stored in the downstream communications channel, which given the limited available bandwidth, may not be the most efficient use of the spectrum.

The addition of memory partially solves the problem of inefficient use of available spectrum space, since the electronic newspaper or mail would not always be present in the system, but rather multiplexed on a downstream channel carrying similar signals to other terminals. Not only does this provide for better spectrum use, but also allows the transportation of more personalized messages.

For this generation of two-way CATV terminal to become feasible, the cost of memory will have to drop substantially, which should result from improved memory technology such as the development of the "bubble memory." This generation also implies substantial increases in the amount of computer power necessary to run the system. With each new generation, the size, speed and computational power of the controlling minicomputer system must be upgraded. Existing minicomputer systems are adequate through the third generation, with the addition of more processing units as the number of terminals in a cable system grow. The fourth generation implies exponential growth in the volume of information requiring processing. It is difficult to speculate beyond this generation because of the rapid development of associated technology, and it is even possible that the fundamental transmission system will itself change to an optical rather than a radio frequency system. It is clear that, in any case, that the technology and the associated new applications will continue to grow in a series of sequential evolutionary

FIGURE 3

Third Generation: Microprocessing



steps.

Summary

One of the greatest problems for the development of two-way CATV technology has been the failure to consider the development as an evolutionary process, but rather as a fully developed technology. Two-way CATV futurists too often claim capability of a fully developed third generation system without thinking through the cost justification for development of the technology to provide that high level of performance. This contributes to the so-called two-way CATV credibility problem.

What is needed is a step-by-step approach to two-way CATV technology shown in Figure 4. The developmental process is considered in evolutionary steps, with simple system monitoring, to interactive response, to formatting both input and output signals, to local terminal memory. Revenue-generating and socially-desirable applications of the technology are associated with each evolutionary stage.

The earliest application is per-program pay entertainment which requires only simple system monitoring. This will be followed by the interactive response applications such as training, interactive advertising and crude forms on in-home shopping. The third generation allows complex reformatting making possible power load management applications and more sophisticated shopping services. The fourth, and last generation described here, opens the way for at least partial realization of the wired nation concept.

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FIGURE 4

The Evolution of Two-way CATV

TECHNOLOGICAL GENERATIONS

APPLICATIONS	FIRST "AREA MULTIPLEXING"	SECOND "INTERACTIVE RESPONSE"	THIRD "MICRO-PROCESSING"	FOURTH "LOCAL MEMORY"
PAY TV	PER-PROGRAM PAY TV			
SHOPPING		INTERACTIVE ADVERTISING	COMPLEX ORDERING	ON-DEMAND CATALOGS
MARKETING RESEARCH	AUDIENCE MEASUREMENT	MULTIPLE-CHOICE QUESTIONNAIRES	COMPLEX QUESTIONNAIRES	SELF-PACED QUESTIONNAIRES
MONITORING SERVICES	HEAT & SMOKE DETECTORS		POWER LOAD MANAGEMENT METER READING	
EDUCATION		FIXED SCHEDULE TRAINING		ON-DEMAND LESSONS
COMMUNITY INFORMATION		PUBLIC FORUM		ELECTRONIC NEWSPAPER/MAIL