THE SUBSCRIBER RESPONSE SYSTEM

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The Need

Communication between individuals or groups in today's world takes place in a variety of ways, each of which involves a particular medium. Many of our habit patterns and our general way of life are strongly affected by the communications media to which we are exposed to or choose to use.

The well-known mass communications media include radio, television, telephone, motion pictures, correspondence (mail), newspapers, and large circulation magazines. With the exceptions of the telephone and mail, these media are largely one-way communications systems from which the general public, may receive information but cannot readily communicate back in the same medium.

One-way communication media have serious drawbacks for those on both ends. The receiver cannot make his individual opinions and needs known without resorting to another medium. And the originator does not have access to those opinions and needs which could be exceedingly valuable. A two-way mass communication medium would, in contrast, not only allow the receiver to express his views, and possibly get what he wants, it also allows the originator to modify his operation for whatever effect he chooses.

The presently available two-way media (mail and telephone) have serious shortcomings for mass communication. The traditional distribution system for mail is slow and expensive, particularly where mass distribution is required; and the telephone is much better suited to communication between individuals than to mass communications.

The public is at a considerable disadvantage under a unidirectional mass communications system. The medium constrains the public to act in essentially a passive role. Reactions and responses to the "downstream" information are either absent, indirect or must get back "upstream" via telephone or mail, with the penalties noted. As a consequence, only a very small percentage of any mass audience responds in any detectable way, and it is extremely costly and time consuming to obtain anything like a precise determination of response.

The reaction of the public to advertising, entertainment, sports or other types of programming is ascertained presently by very limited surveys conducted after the fact. It is consequently difficult for private corporations or governmental agencies to know what the public accepts, rejects, or is willing to purchase until the

acid tests of sample polls, sales reports or vote tabulations reveal the facts. Even reasonably rapid responses are not generally possible, and the validity of extending the results from selected population samples to the entire public may be questionable.

The explosive expansion of the freeway system and the wide acceptance of air travel has resulted in a complete change in business and social habits. It is commonplace for a businessman to fly cross country for a short meeting - whereas in earlier times the business would have been conducted by letter or telephone. In a similar manner, the housewife makes use of her automobile to travel relatively long distances for food and other shopping services.

Increasing public interest on the effects of pollution as well as the growing inconveniences due to congestion in the airways and freeways may well augur another change in life style, particularly if an acceptable substitute can be found. The key to a new life style could well be an adaptive two-way communication system in which people could perform a greater portion of their work, make more of their purchases and receive even more of their entertainment without leaving their homes or offices.

Another universal need which is not adequately satisfied by current media is emergency communication of medical, fire, intrusion, and other alarms to the proper agency without delay and at a reasonable cost.

Other examples could be cited in which presently available communication methods do not adequately satisfy human needs. Even more disturbing is the realization that technological limitations inherent in the present media not only prevent resolution of these difficulties and shortcomings but also allow for little foreseeable growth to answer needs which have been clearly recognized by both government and industry alike. Moreover, such communications requirements will in fact constitute the very corner stone upon which the life styles in this and future decades will be based. In its response to the F.C.C., (Docket #18397 - The Future of Broadband Communications) the IED/EIA stated that "--- The mushrooming growth in available information and the demands for access to this information is bringing about a revolution in communications which will produce a profound change in the very way society is structured and in the way we live."

The need, concisely stated, is for a widely available, broadband, two-way communications system that can rapidly handle large amounts of information in both directions. In other words, a mass communication system that can actually be used by the masses. It need not compete destructively with existing media but could, complement the impressive communication services we already enjoy.

Such a system would have to meet the present and emerging needs for sound, pictorial, and data transmission and allow for undefined future growth by economically viable modular expansion.

The Means

Cable television, the one-time stepchild of broadcast television, now appears as the leading candidate to solve the major communication needs cited. Here again the IED/EIA states that, "The terms "CATV" for Community-antenna television and "CTV" for cable television fail to do justice to the potential of the medium." The great natural assets of CATV is that its facilities are either in now or are planned and the new two-way services can be provided requiring only a relatively small incremental unit investment. Further, it can be expected that the additional revenues resulting from both these new services and associated increased market penetration will provide the system operator with greater financial resources necessary to keep pace with anticipated growth demands. The 300 MHz electromagnetic spectrum contained within the radiation-tight cable does not violate free space as does the emanations of off-the-air television. Once having exhausted the initial 300 MHz capacity to meet present needs, additional 300 MHz bandwidth units can be added by the expedient of additional small diameter coaxial cables.

The technology for installing a cable system is similar to that now providing universal telephone and power service to the entire country. It requires no technological breakthrough to conceptually substitute coaxial cable for wire and visualize a nation wired for broadband cable service limited only by customer demand. The next logical step is the expansion of such a service into two way operation.

Two-way use of cable television is already technological feasible: either by simply utilizing separate downstream and upstream cables or by simultaneous bi-directional signalling on a single cable with frequency multiplexing and two-way amplifiers and filters.

Viewed broadly, therefore, the solution to interactive, universal communication is in hand. There remains however, the choice of a specific implementation: the selection of a specific sub-technology to accomplish this two-way communication. But this is really a second priority decision. The first requirement is to define what the system is to do in a market which has not yet been proven. Which of the inadequacies of the present media and which of the foreseen needs should be addressed first in the choice of system design parameters and techniques?

Another fundamental question is that of design obsolescence. Should considerations of low cost installations in this fledgling market override the risk of relatively early obsolescence as public acceptance and usage grow rapidly? Or should a system be devised wherein growth capability and modular expansion are integral parts of the design plan.

Recognizing the uncertainties of customer acceptance and the time span required to fully exploit the services offered, Hughes has elected to approach the problem from a systems viewpoint. We have, designed a complete two-way communications system rather than a single device or service.

The total system approach has produced a design that can grow to meet the long term goals and does not attempt to prejudge the relative value or eventual marketability of services to be offered.

The System

The Subscriber Response System (SRS) is designed to permit the cable system operator to add two-way communication capability with a modest initial investment and yet be able to expand in a modular fashion as the number of subscribers, the traffic, and the demand for additional services increase - all without obsolescence of previously installed equipment.

The Subscriber Response System is shown in Figure 1 incorporated into a typical CATV system. The two-way communications take place between a computer complex termed the "Local Processing Center" (LPC) and the Subscriber Terminals located in the subscribers' residences or places of business. The LPC equipment shown in Figure 2 can be located at the Head End, at the Local Origination Studio, or remotely from the local CATV system.

Depending on the choice of location, signals between the LPC and the Head End are fed by cable or microwave relay. At the Head End, the downstream SRS signal is frequency multiplexed with the normal CATV video spectrum and sent downstream through the cable network, including the existing trunk and distribution system.

At the subscriber's home or business location, the composite signal at the normal drop line cable is routed to the Modem Unit of the Subscriber Terminal shown in Figure 3.

The Modem frequency converts a 26 channel TV spectrum and furnishes a fixed frequency signal to the TV set, normally channel 8 or 12, thus eliminating a separate frequency converter. The Modem performs all of the radio frequency modulation and demodulation and most of the digital signal processing required at the Subscriber Terminal. It also furnishes the interface for all accessories used in the system. The Modem requires no operating controls and is designed for installation at an unobtrusive location, nominally behind the TV set.

All operating controls for the terminal are located at the Subscriber's Console shown in Figure 4. The Console is interconnected to the Modem by a small diameter cable which allows approximately 50 feet separation between the units depending on the installation requirements at the subscriber's location.

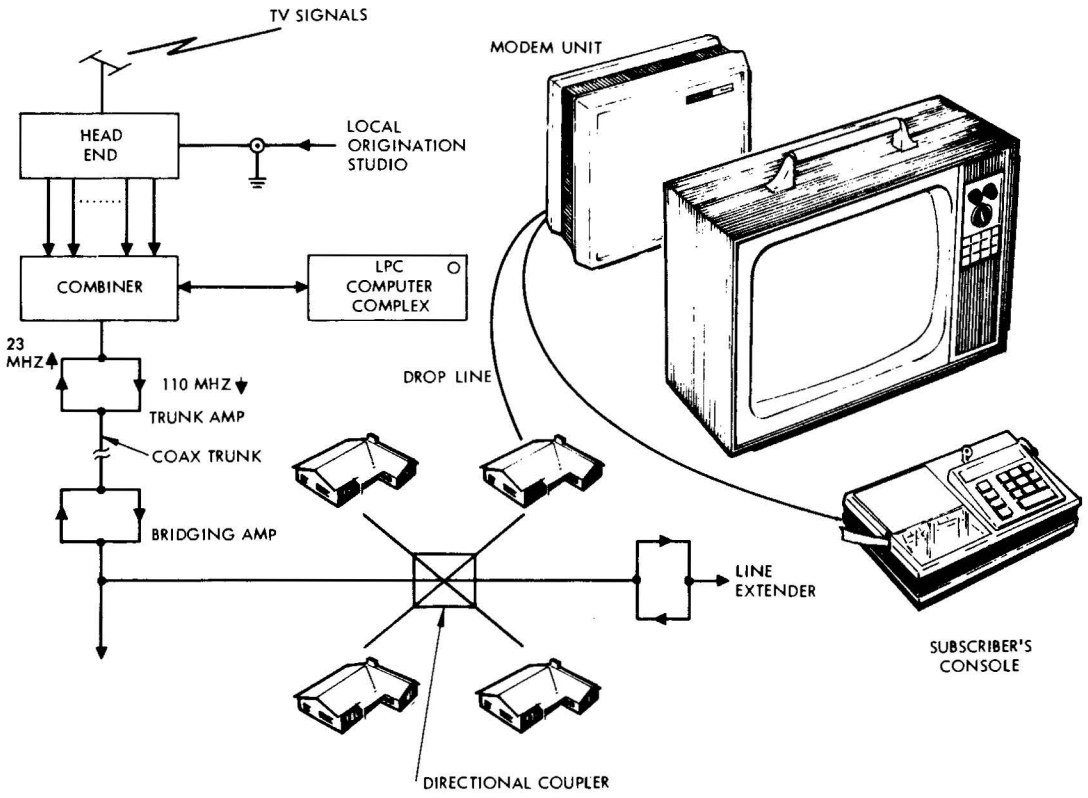

Figure 1. Overall CATV Two-Way System

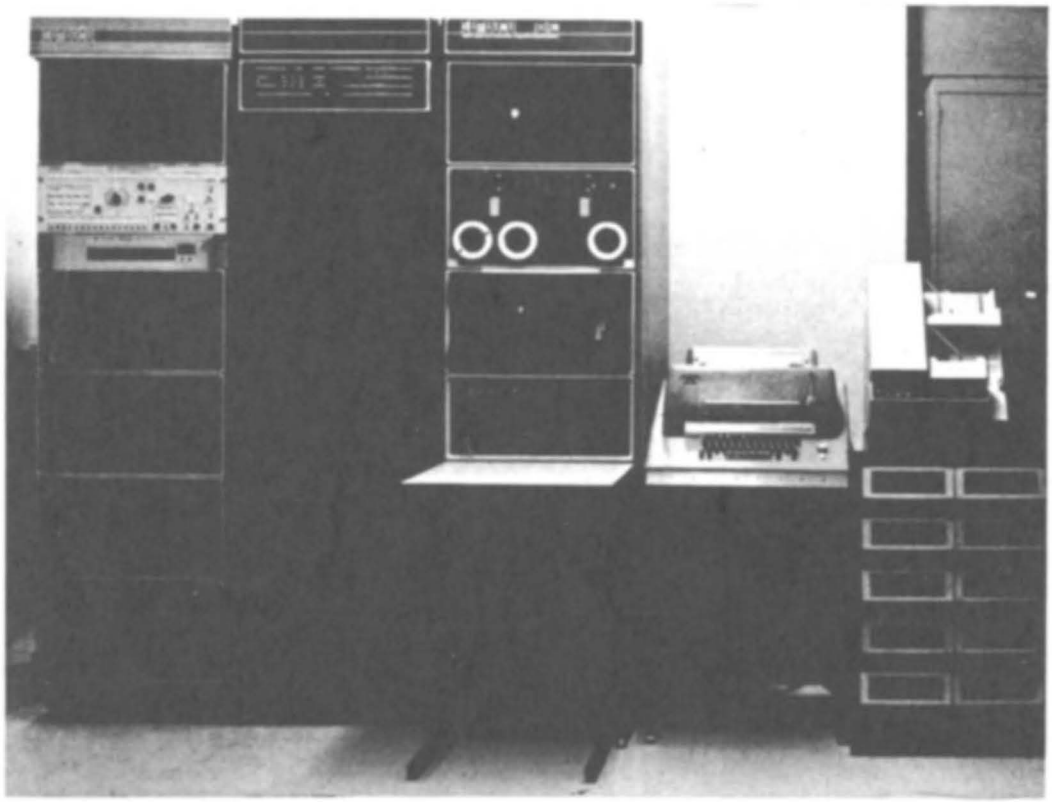

Figure 2. SRS Local Processing Center

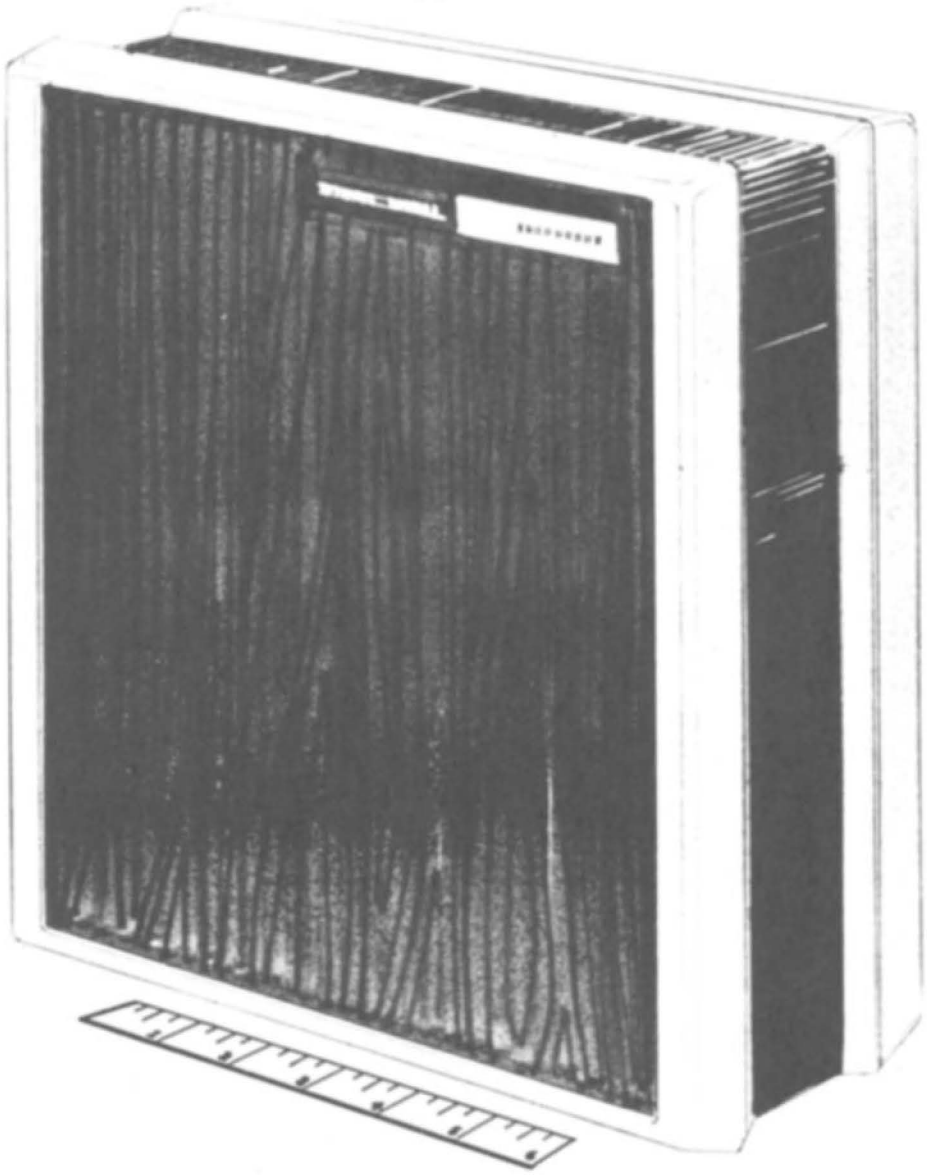

Figure 3. SRS Subscriber Terminal Modem

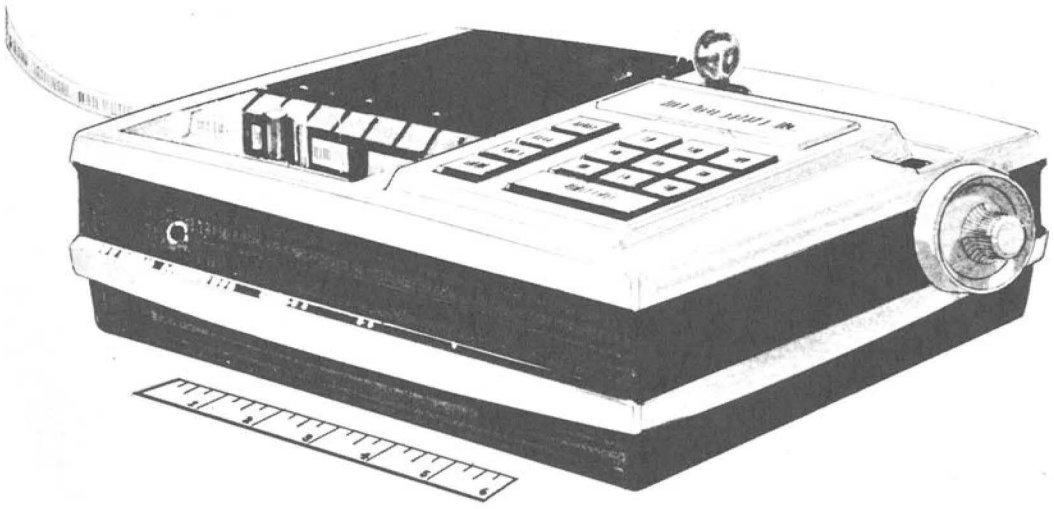

Figure 4. SRS Subscriber Terminal Subscribers' Console

In addition to a TV Channel Selector Switch the Console contains a keyboard and a small strip printer allowing the subscriber to engage in two-way communications with the Local Processing Center.

Communications upstream from the Subscriber Terminal to the Local Processing Center are transmitted back from the Modem either over the same cable network with suitable upstream amplifiers and filter networks to by-pass the existing downstream amplifiers, or over a separate cable in a two cable system.

The resulting spectrum of signals on the cable is shown in Figure 5. The downstream SRS signals occupy a 4 MHz bandwidth from 108 to 112 MHz. The downstream form of communication is digital pulse code modulation (PCM) at a 1 Megabit per second rate. The digital data is then used to frequency shift key (FSK) a 110 MHz carrier.

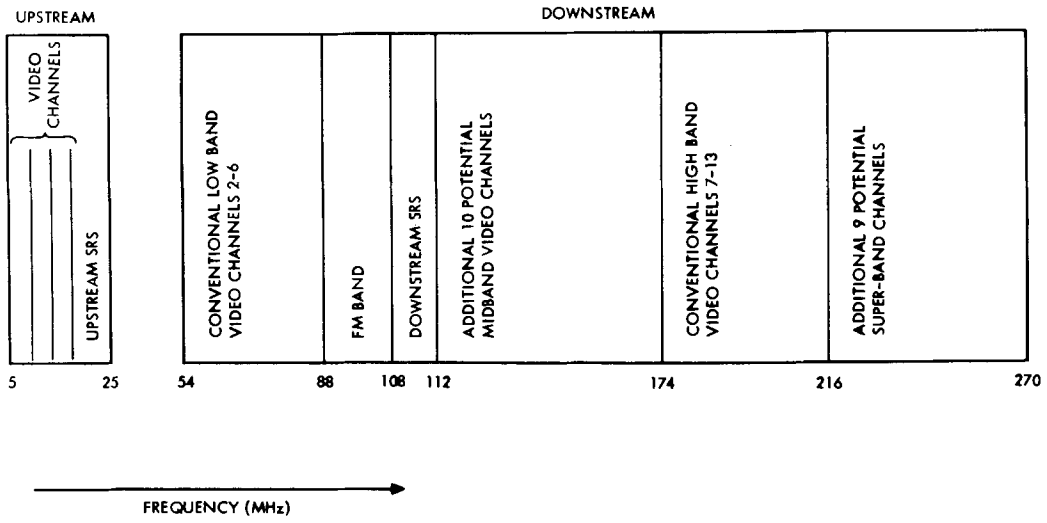

Figure 5. Cable Spectrum Allocation

The upstream signal occupies a 4 MHz bandwidth extending from 21 to 25 MHz. Again the communication is via digital PCM at a data rate of 1 Megabit per second. In this case the digital data is used to phase-shift key (PSK) a 23 MHz carrier.

A typical communications sequence that illustrates the basic principles of operation of the SRS system is shown in Figure 6.

All communications are initiated in the Subscriber Response System at the Local Processing Center. The LPC sends an interrogation message addressed to each subscriber in sequence at a periodic rate. The meaning of the interrogation message is basically the query "Do you have requests?" The Subscriber Terminal will always reply to the interrogation with any of a number of possible requests or statements. The subscriber's replies will be sent upstream

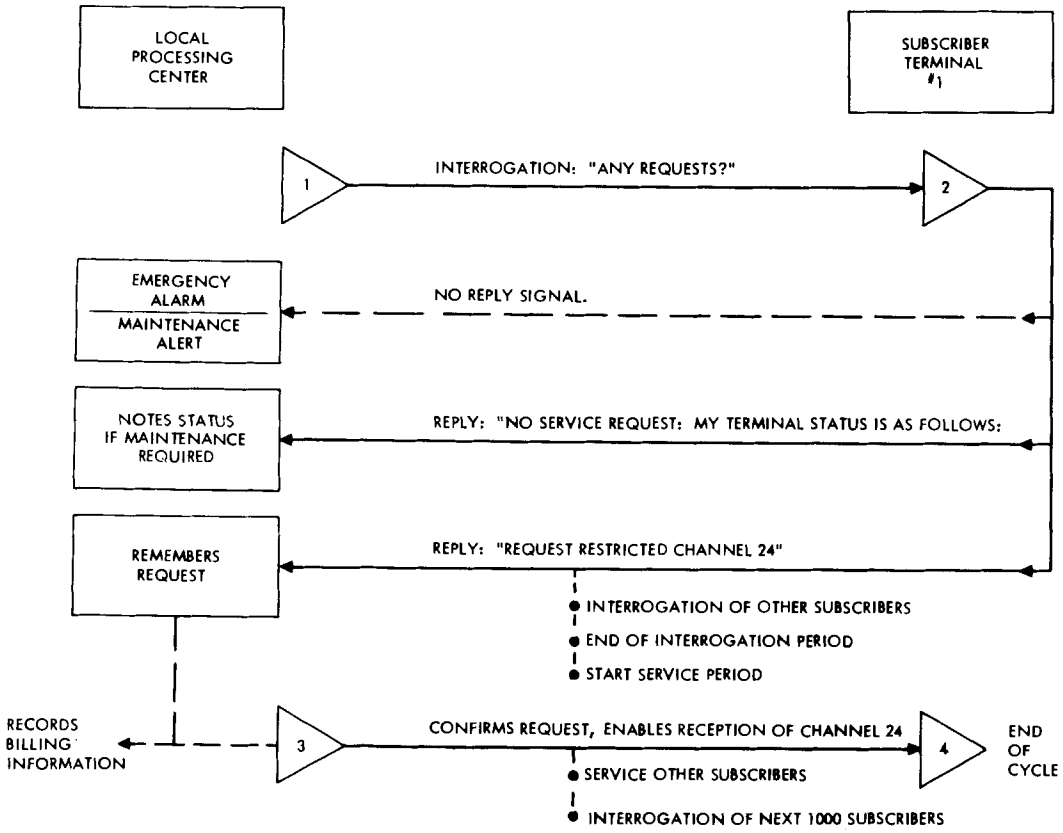

Figure 6. Typical SRS Communications Sequence

bearing the subscriber's address followed by a number of bits devoted to the content of the message. The absence of a return signal from the subscriber will indicate either a physical break in the cable path to his location or a defective Subscriber Terminal. The Local Processing Center will recognize the absence of an expected signal and take appropriate automatic action: it will post a maintenance alert for service personnel and will also flag a potential emergency alarm to cognizant police or protection agencies when such service is requested.

If a particular subscriber has initiated no requests when his terminal is interrogated, the terminal will automatically reply, giving a terminal status report. The terminal status report will indicate the state of the terminal with regard to proper functioning of the terminal circuitry, the condition of accessory devices, and other diagnostic information. The LPC will note the terminal status and take appropriate action.

When a subscriber has initiated a prior request his reply to an interrogation will indicate his address and the particular request, rather than the terminal status report. In the example shown in Figure 6, he requests permission to view a "restricted

channel", which might be programmed at that time for a medical lecture restricted to eligible doctors or other eligible professionals. In this case, the LPC will check his request and eligibility to view this program on the particular channel at that time. If the subscriber is eligible, the LPC will remember the subscriber's address for future action. If he is ineligible, the LPC will take no further action.

Each subscriber is interrogated in turn until a group of 1000 subscribers has been processed. Following the interrogation period, the LPC then services the subscribers' requests. In the case illustrated in Figure 6 the LPC will send a downstream message to the subscriber enabling his TV video reception for the restricted channel requested; at the same time the LPC will prepare a billing record (assuming there is a charge for this program) on magnetic tape indicating the subscriber's address, the channel requested, and the time. (Alternate information could be substituted readily for differing requirements). At the end of the weekly or monthly billing period the magnetic tape could be used either at the LPC or another location to prepare actual billing statements for forwarding to the subscriber.

When 1000 subscribers have been interrogated and serviced, the process is repeated for the next 1000 subscribers and so on. The maximum capacity provided in the present system is approximately 65,000 subscribers per Local Processing Center.

For the larger capacity systems which will eventually be required in densely populated metropolitan areas, it may prove more efficient to centralize the Local Processing Center so that it can service a number of Head Ends. The centralized LPC would use a full-sized computer system rather than a minicomputer; it would be a faster unit with greater computing power, more storage capacity, and a greater selection of peripheral devices. Conversely the data handling equipment required at each Head End would be considerably reduced. The central LPC would be interconnected with the Head End two-way data interfaces by cable or microwave relay.

While it was previously stated that the Local Processing Center rather than the subscriber initiated all communication contacts, the communication sequence is so rapid that the subscriber subjective reaction is that he initiates all contacts. Typically for a system of 10,000 active subscribers the time required for a subscriber to receive a reply in response to his manually initiated request (i.e. depressing a key) will be less than 2 seconds, even in the prime times of heavy evening hour traffic.

The SRS system design provides functions necessary to provide a long list of potential services. Even services which appear to be purely visionary at the present time can be provided by later versions of SRS Subscriber Terminals without obsolescence of the earlier terminals or a major redesign of the system.

A listing of services that can be provided by existing designs of the SRS system is shown in Figure 7. As indicated earlier the SRS Console provides remotely controlled channel selection. At the present time, provisions have been included to select 26 possible channels by a voltage-controlled varactor tuner located in the Modem Unit.

- REMOTE CHANNEL SELECTION
- PREMIUM TV
- RESTRICTED TV
- CHANNEL POLLING
- OPINION POLLING
- EMERGENCY ALARMS
- METER READING
- ACCESSORY POWER CONTROL/TIMING
- TWO-WAY MESSAGE CAPABILITY

- SYSTEM DIAGNOSTICS
- SYSTEM CONTROLS
  - MASTER ENABLE/DISABLE
  - TRANSMIT ENABLE/DISABLE
- ERROR RESISTANT TECHNIQUES

Figure 7. SRS Present Services Capability

Six of these channels have been reserved for Premium Television usage, whereby the channel, at the control of the Local Processing Center, may be made available to the subscriber on a fee basis for premium cablecasting such as the showing of first run movies, live dramas, musicals or sporting events. The subscriber is required to indicate by a positive action (depression of a Premium TV key) that he wishes to purchase a program on the channel to which he is tuned. His request is immediately granted by an enabling of the video on his set, and he is automatically billed at the LPC. Provisions have also been included to allow free previewing periods on all Premium channels which can be individually varied in time of occurance and duration by the cable operator.

The restricted channel concept, alluded to earlier, is similar to that of Premium TV. It involves, however, eligibility as an additional requirement. The possible usages are numerous, including use by professional groups and societies, home educational programs, religious or other specialized interest groups, business meetings and home seminars, and adult video programming. Two channels are provided for restricted use in the present SRS design.

Both Premium and restricted channels, however, may be converted back to standard TV channels at any time by control signals from the Local Processing Center.

The restricted channel concept and implementation can be readily extended to include the enabling of groups of channels on a long term or permanent basis. This would allow the cable operator to base monthly rental charges on the number of channels to which the subscriber wishes access.

Channel Polling, somewhat analogous to the well-known Nielson type ratings is provided in the SRS system. In contrast to the limited sampling provided by currently available polling systems, the SRS system can provide polling of all subscribers in a CATV system on a program basis. It can also sample viewer response every few seconds if desired to obtain the response to political announcements, spot commercials, etc. The results of the channel survey can be displayed in a variety of ways. For example, within 5 seconds of the actual survey, a graphics display terminal shown in Figure 8 available as an accessory at the Local Processing Center, can be programmed to produce a histogram, illustrated in Figure 9. A hard copy readout is also available. The demographics of CATV system subscribers can also be correlated with the channel polling results or used to determine selective polling of particular subscribers or groups of subscribers.

Opinion polling in the SRS can range from simple "Yes", "No", or "Undecided" answers to TV video originated questions, to coded replies to more elaborate video or mailed questionnaires. Correlation and display of opinion polling results can be handled as flexibly as the techniques described for channel polling.

Any existing emergency alarm system - fire, intrusion, medical, etc. - can be monitored by the SRS system. The emergency signal is given priority over all other transmission, it is sent by the SRS Modem upstream and notifies the LPC of the address of the subscriber and the time and identification of the alarm or alarms. The LPC verifies the validity of the alarm, by immediate reinterrogations and sends a notification to the proper governmental, medical or protection agency - within seconds after the occurrence. The

Figure 8. Graphics Display Terminal

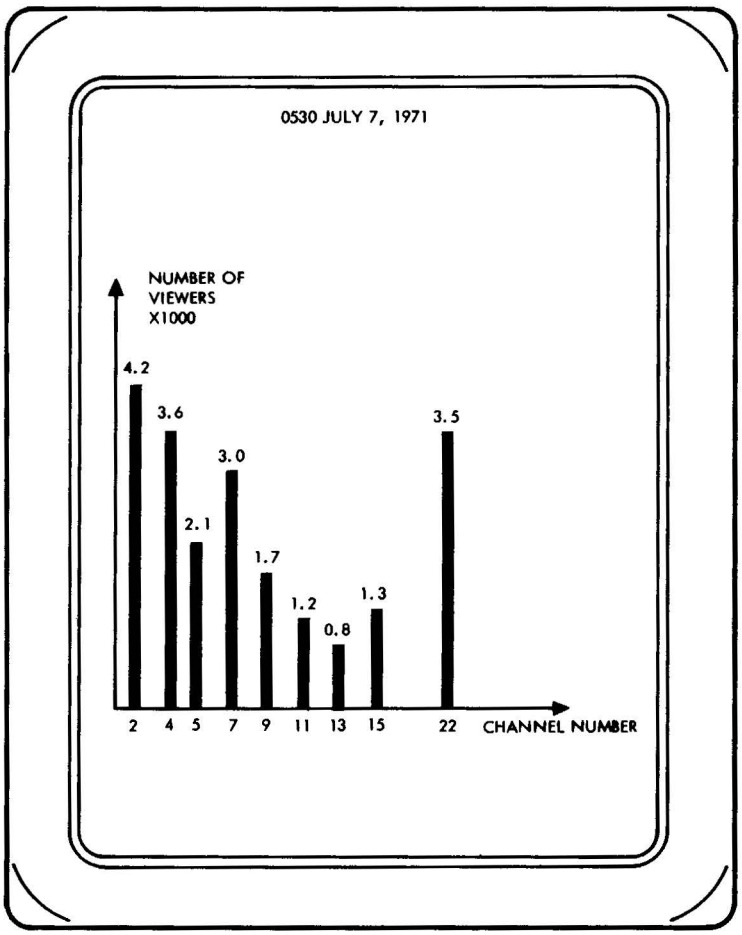

Figure 9. Channel Polling Display

LPC also verifies that proper action has been taken by sending a confirmation signal to the subscriber's terminal which basically resets the terminal releasing it from its locked condition and enabling it to be used normally. As mentioned earlier, a cut cable or non-functioning terminal would be detected at the LPC and treated as an emergency condition.

Various forms of data including meter reading can be automatically read out of the Subscriber Terminal by LPC command. Up to 20 digits per Subscriber Terminal can be transmitted upstream in a single burst which would provide for four-five digit utility meters for example. With an appropriate accessory switching unit, entire apartment dwellings could be read out through one SRS terminal.

By prior arrangement with the Local Processing Center, the subscriber can be provided with accessory power control or timing signals at any desired time. The potential application of this service include the control of power to accessories. For example, a video tape recorder could be turned on automatically to record a desired program. Other uses include wake up alarms, automatic sprinkler systems, and so on.

The SRS system is also provided with a two-way message capability. Upstream messages are initiated by the subscriber at the small numeric keyboard shown in Figure 4. The subscriber may enter messages in groups of up to twenty characters at a time. Assuming the message required more than 20 characters, the "Busy" indicator would light after entering the first 20. With a second or two the "Busy" lamp would be extinguished, indicating the LPC has received the message, and the remainder of the message could then be entered. As the subscriber enters the keyboard data, each character is printed on a half inch paper strip, allowing him to check for errors and providing a permanent hard copy record of purchases or other financial transactions.

Alphanumeric character messages may be transmitted downstream by the LPC, and would also appear on the strip printer. Alternatively, it is planned to offer as an optional accessory at the Subscriber Terminal a paragraph printer which would permit the downstream transmission of lengthy downstream messages at rates of 100 words per minute or greater.

The utilization of two-way message capability has manifold applications, some of which are listed in Figure 10. A full discussion of the applications is beyond the scope of this paper, but the generalized approach involves some form of coding and the insertion into the message of numerical data which specifies the request. The coding required could be furnished by mail in printed catalog form. Naturally occurring numerics such as credit card data, quantities, dates, time of day, etc., could be entered normally. Punctuation marks available from the keyboard would be used to separate logical message groupings for proper interpretation at the Local Processing Center. A typical message sequence using such coding is shown in Figure 11.

- HOME SHOPPING
- EDUCATIONAL INSTRUCTION
- RESERVATION SERVICES
- STOCK MARKET TRANSACTIONS, 'ORTS
- QUIZ SHOWS
- MAIL/ADVERTISING
- DATA BANK ACCESS

Figure 10. SRS Two-Way Message Capability

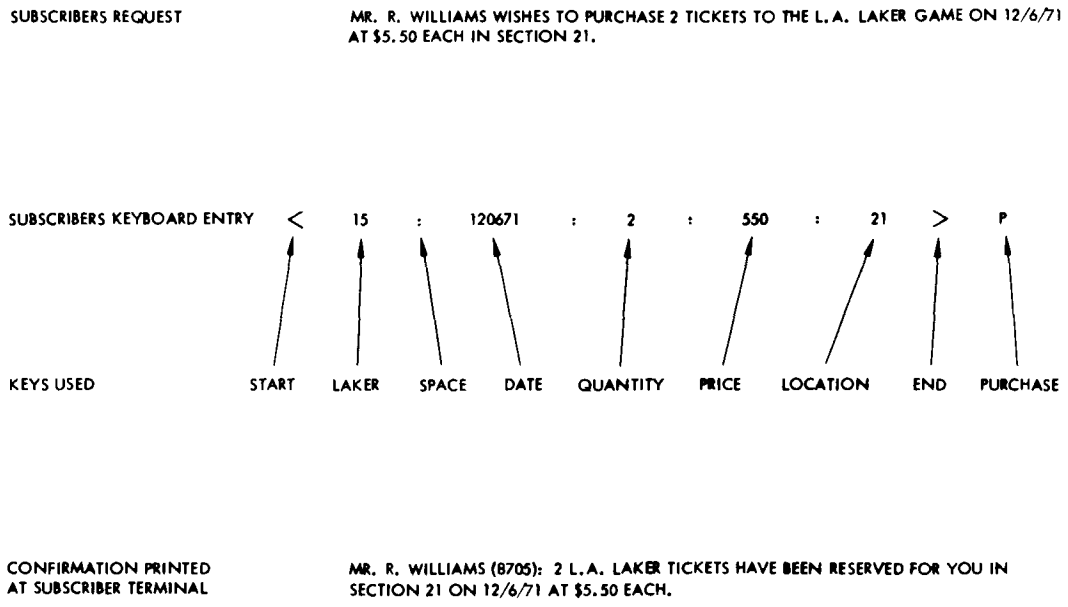

Figure 11. Typical Message Sequence

The discussion of services can be concluded with mention of services which are primarily useful to the CATV system operator, particularly with regard to the maintenance of high reliability of the CATV system.

The system design includes both hardware and software for self diagnosis of system malfunctioning. Provisions, have been included, as previously mentioned to diagnose individual terminal malfunctioning or outages, and cut or defective cables. In addition the terminal can detect and subsequently transmit indications of loss of power, noise bursts, loss of incoming carrier, and downstream parity errors.

The LPC will also detect loss of upstream carrier, noise bursts, power failure, upstream message parity errors, and malfunctioning in the computer and its peripherals. The LPC can also command off the transmitter of any suspected errant subscriber terminal, and can completely disable the terminal if desired for any reason.

Several other error resistant techniques have also been included in the system design which will drastically diminish the probability of error. Among these are dual transmission of all infrequent commands and the requirement for confirmational commands from the LPC to the terminal to indicate the satisfactory completion of particular message sequences.

Two models of the Subscriber Terminal have been planned at the present time. In addition to the SRS-102 model shown previously, a simpler, lower cost version, the SRS-101, is available without the strip printer and associated electronics. This model, shown in Figure 12, has four keys rather than the full keyboard furnished with Model SRS-102. The keys provided will enable purchase of Premium and Restricted TV, opinion polling, and TV shopping with a more limited coding capability. TV Channel Selection is of course retained in this model, and the Modem Unit remains substantially the same as in Model SRS-102. With the exception of the printer deletion, and reduced keyboard size, the SRS-101 can provide all other functions listed in Figure 7. The SRS-101 and SRS-102 are fully compatible and can be used interchangeably in the SRS system.

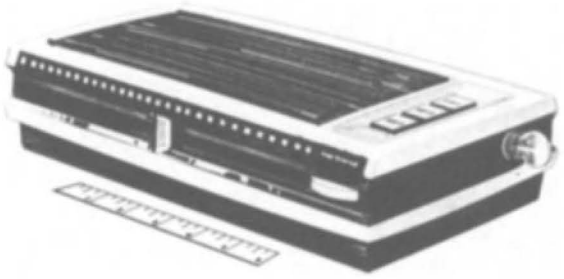

Figure 12. SRS-Model 101 Console

With regard to system growth potential Figure 13 illustrates some of the technically feasible increases in capability which can be modularly added to the SRS as the market demand warrants.

The Hardware

The SRS functional system diagram is shown in Figure 14.

The Local Processing Center described contains a standard PDP-11 mini-computer, including 24K words of core memory and a Model 35 Teletype. An Input-Output Processor has been designed to convert the parallel input-output of the PDP-11 into a serial form for transmission and reception of signals on the cable. For the prototype system the peripheral equipment includes a time of day clock, a 256 K word disc memory, a 7 track magnetic tape drive unit a card reader and a graphics display terminal together with hard copy readout.

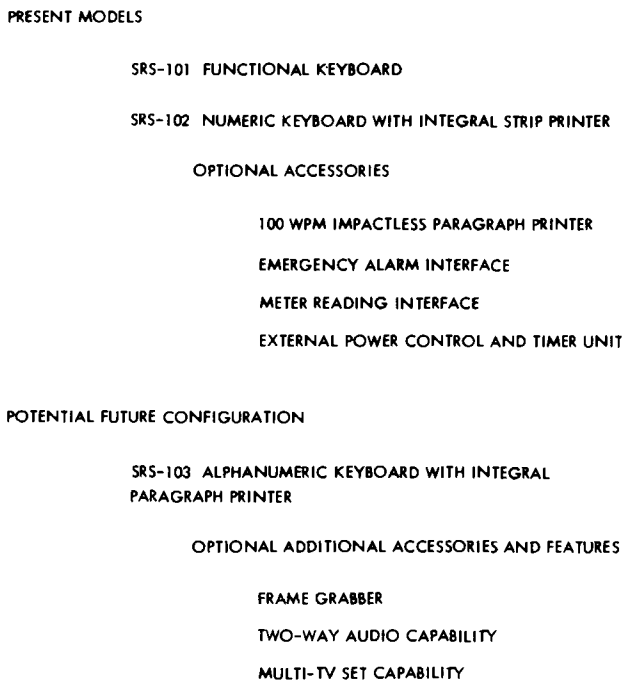

Figure 13. SRS System Growth Potential

The required type and number of peripheral equipments for operational use will, of course, depend on the nature and number of the services provided, the number of subscribers in the system and the anticipated or actual traffic volume. Modular expansion capability is also provided in the LPC and software design to accommodate such growth situations.

Inputs to the computer can be made by punched cards or paper tape, or by manual operation of the teletypewriter.

The LPC system is designed to operate unattended except for routine maintenance. Manual inputs for special programming can be made by remote teletype interconnection or by use of the Model 35 Teletype at the LPC.

At the Subscriber Terminal, the downstream TV video is separated from the 110 MHz SRS signal and is routed to the varactor tuned frequency converter which furnishes the video input to the TV set. The 110 MHz signal is demodulated and 1 Megabit digital data processed in the Modem Unit to furnish signals to the frequency converter, external accessories or to the Operator's Console depending on the particular message sequence.

Upstream data originates at the Operator's Console, or at the accessory sensors and devices. It is encoded and stored at the Modem to await upstream transmission. In transmission the data is fed to a 23 MHz phase modulator, passed through a low pass filter and on to the subscriber's drop cable.

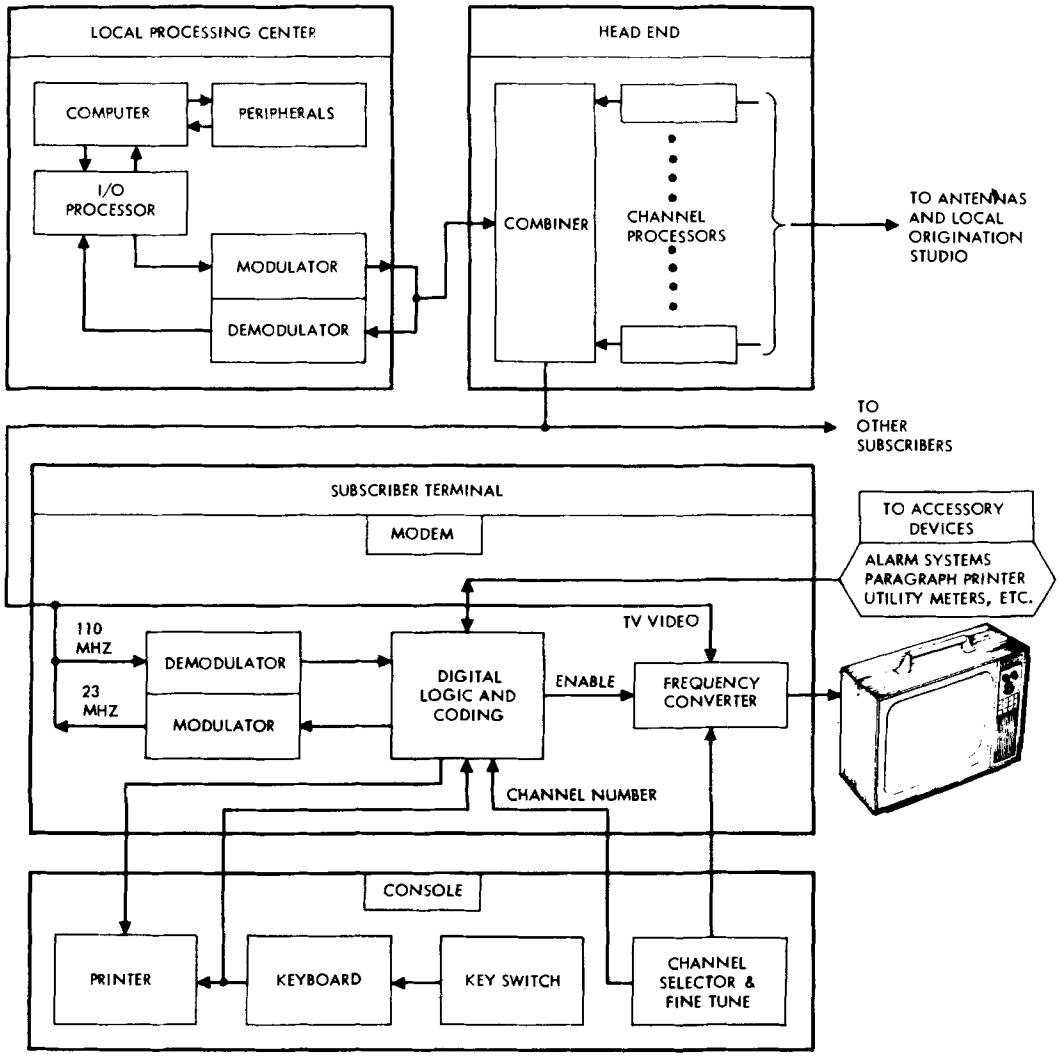

Figure 14. System Functional Block Diagram

Integrated circuitry of the TTL and MOS varieties is used widely in the Prototype Subscriber Terminal. Future plans for large quantity production include the use of large scale integration to further reduce size, cost, and power consumption and to increase system reliability.

Status

Some of the areas of technical concern in the design of any digital data communications system are:

1. A determination of the required bandwidths
2. The required bit error rate.
3. The effects of impulse and other noise forms.

4. The effects of various transmission deviations caused by the cable system and its associated components on system performance.

In designing the SRS system, these concerns were taken into account as were human factors considerations in designing the Subscriber Terminal.

In order to confirm design expectations and to answer questions that can only be resolved by actual trial, a demonstration system was completed early in 1971. This system consisted of a Modem and an Operator's Console shown in Figure 15 and 16. In addition, a small simulator (Figure 17) was designed to produce driving stimuli for the terminal to simulate desired features of the LPC. The demonstration system has been extensively tested both at the Hughes facilities in the Culver City area and on an experimental Tele-Prompter two-way cable system at Los Gatos, California. While this testing is continuing, the results to date have validated the design concept. All of the present system functions described previously herein were successfully demonstrated repeatedly even in the presence of near band burst transmissions in close proximity to the equipment. While measurements are still incomplete bit-error rates appear to be in the 10^{-6} to 10^{-7} range which correlates with expectations. Message errors which remain undetected in the system are expected to be orders of magnitude less than the bit error rates as a result of the error compensating message sequencing and verification techniques employed.

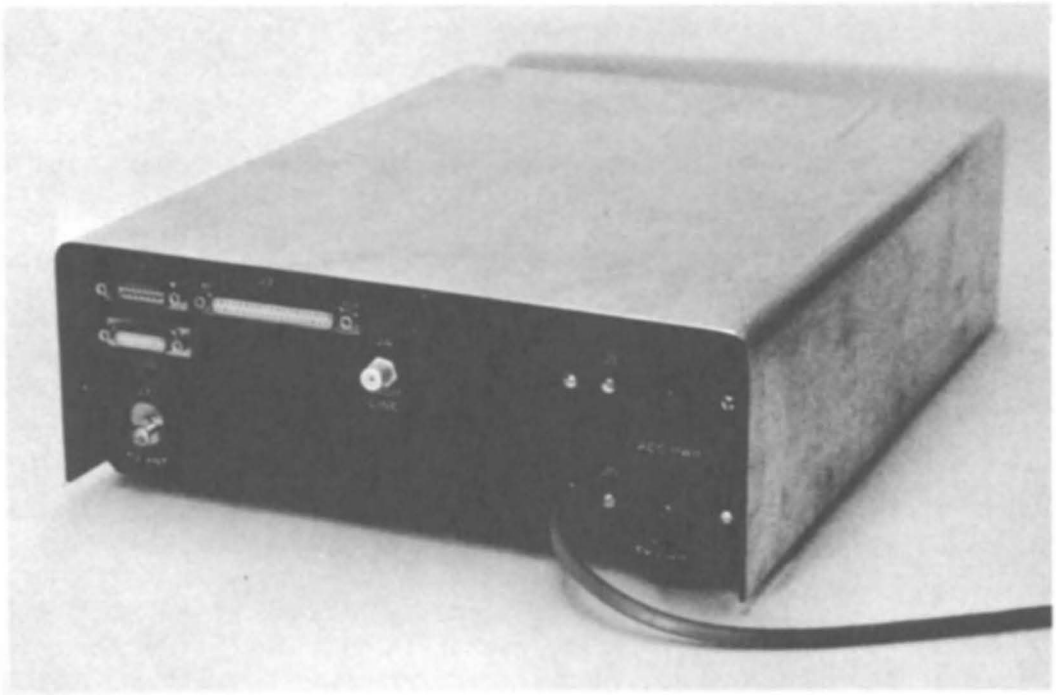

Figure 15. Subscriber Terminal - Demonstration Modem

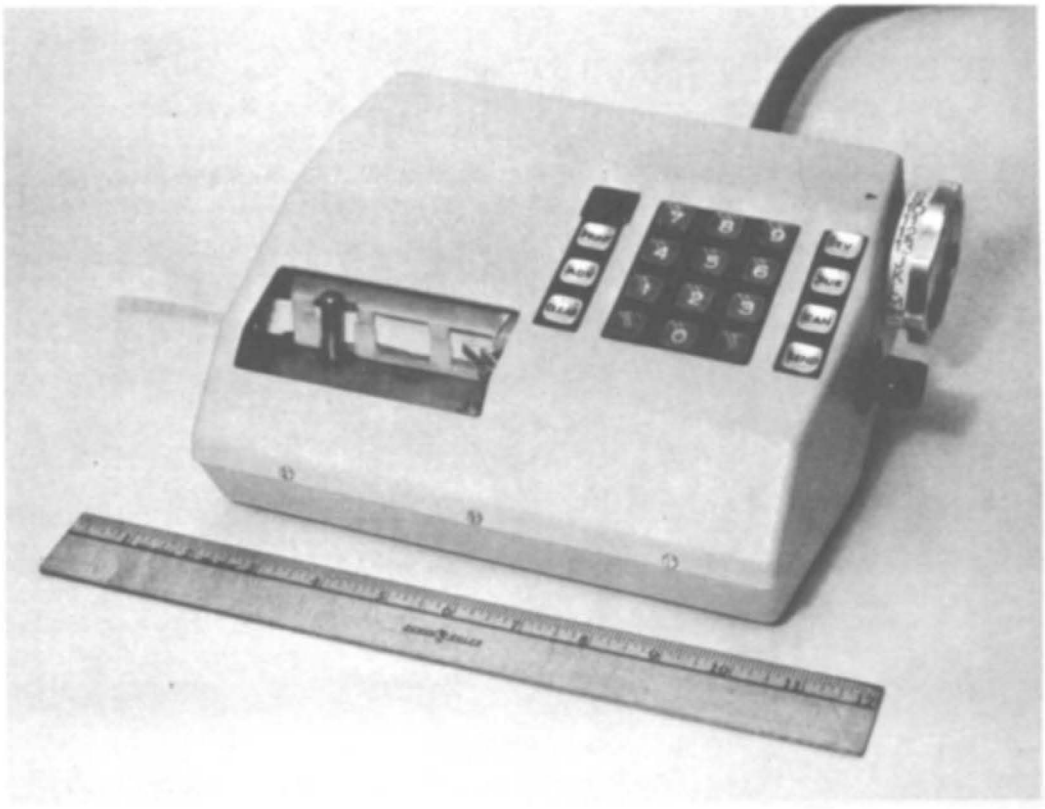

Figure 16. Subscriber Terminal - Demonstration Console

At the present time software designs are being completed and hardware is in production to permit a small scale but intensive field test with approximately twenty-five SRS Subscriber Terminals and a fully equipped Local Processing Center. The test will be conducted in the Los Angeles area on an operating cable system starting in the last quarter of 1971. It is expected that the test will include both technical and consumer oriented features to demonstrate the SRS system capability and to obtain the consumer reaction to the services offered.

Pending the results of the small sample to be tested later this year, and continued consumer surveys, plans are being formulated for the large scale production of SRS equipment by the Theta-Comm Company. This equipment will be used in a system wide test in 1972.

Conclusion

While it is impossible to predict the rate of public acceptance of two-way systems, we believe that they will be widely accepted. With this conviction, and a strong commitment to the future of communications, we submit that any two-way mass communication system worthy of serious consideration must meet the following vital requirement.

Figure 17. LPC Simulator

The system must have a well thought out approach allowing for the impossibility of predicting the market accurately.

- It must not be limited by prejudgement of the relative saleability of services.
- It must be flexible to change without becoming unwieldy or obsolescent.
- It must be economically viable as well as technically sound and reliable.
- It must deliver what is promised not only from a hardware standpoint but even more importantly from a software view.

We believe that the Subscriber Response System meets these requirements. It has not only the basic capabilities to meet a wide variety of existing needs with minimum cost but also the growth potential to mature with the market in whatever direction it may develop.