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ABSTRACT

The current state (in 1970) of cable television systems is discussed under headings of head end, distribution, home terminals, system performance and standards with close attention paid to the technology involved. In summing up new system planning, the review considers channel expansion, channel reuse, two way cable, local distribution services and integrated circuit technology. Looking slightly further into the future under proposed systems, the potentials of subscriber response services, communications satellites, and lasers are discussed. It is the author's contention that unpredicted advances in related technological fields make the five to ten year growth pattern for cable television not subject to technological limitations; the controlling factors will instead be public need, the incentive and foresight of cable entrepreneurs, the opposition of established communications media, and the decisions of regulatory bodies. (RH)

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The Real World of Technological Evolution In Broadband Communications

By

Hubert J. Schlafly

September 1970

A Report Prepared for the
SLOAN COMMISSION ON CABLE COMMUNICATIONS

The opinions expressed herein are the views of the author and do not reflect necessarily the opinions of the members of the Sloan Commission on Cable Communications or of the Alfred P. Sloan Foundation.

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SECTION

I

INTRODUCTION

This paper has used as a guide the outline paragraph "technology" suggested as one of the "several analytic studies" in the memo of Stephen White to Professor Edward S. Mason, dated May 28, 1970. Following the tone of that memorandum, this study will deal with more than just a tutorial description of terms and hardware and systems. It will also try to present the technologic growth pattern, describe some of their growth incentives and analyze technologic distinctions between cable and other existing communication services.

The writer is aware of the temptations of "blue sky" reporting. If indulged, it will be identified as such. However, the technology has progressed farther and faster than members of this commission and staff might know - even faster than many of the seasoned cable system operators might know, or choose to believe. The factor responsible for this growth pattern is timing. Cable communications has appeared on the scene of history at a time of explosive expansion of related technologies. Data theory, computer design, solid state circuitry, orbital vehicle control, communication theory, and a vast cadre of highly skilled engineering companies and personnel ready to apply this know-how, was not created by the cable industry but have converged at a point in time ready for efficient and immediate use by the cable industry. Therefore, earlier time cycle standards, even those of our own generation, for an industry building on new technologic developments, do not now apply to cable communications. The five to ten year growth pattern under examination by this commission is not technology limited. The controlling factors will be:

1. The desire and true public need for and the productive use of broadband information service and entertainment access for the home.

2. The incentive, foresight and wisdom of industry and other leaders who must marshall the risk capital, realistically appraise the political and competitive fights, and supply the energy to make this happen.

3. The effectiveness and magnitude of opposition of established services whose immense plant investments or carefully developed profit patterns caution them to let new services happen "all in good time."

4. The vision, energy and competence of regulatory bodies.

SECTION
II

SPECTRUM UTILIZATION (See Table I)

The highway over which the produce of communications can be carried to and from market is the electromagnetic spectrum. AM radio, television broadcast, mobile radio, microwave, and even visible light, are electromagnetic waves that can exist simultaneously and distinctively in the space around us. The distinction is that they occupy different portions of the electromagnetic spectrum. Each signal rides on a different lane of the highway, identified by its frequency number, i.e., the oscillations per second of its carrier wave. Physical laws govern the characteristics of propagation through space of each frequency, how the wave behaves in the atmosphere, the effect of physical obstacles or ionized areas, the means by which it can be formed into directed beams or radiated in all directions from the antenna, etc. Interestingly enough, the speed of propagation through space is not a function of frequency; it is the same as the speed of light.

Signals radiated into the atmosphere can be collected by an appropriate antenna and "tuned" by a receiver. In this manner, one distinctive frequency (whose occupancy of the spectrum is regulated by the Federal Communications Commission) can be captured and amplified. Then, the intelligence (dots and dashes, or voice or pictures or data) on that carrier can be "demodulated" and reconverted to a form familiar to human sensory organs or to "talk" suitable for machines. Obviously, if two signals occupy the same frequency at the same geographic location there will be "interference" between these two signals. The annoyance of this interference depends upon the relative signal strengths and the method of "modulation" (the means for impressing the intelligence on the carrier).

To avoid interference radiated signals must be separated in:

a. Frequency – what part of the spectrum is used.

b. Location – sufficient separation between transmitters so that the interfering signal strength at a receiver location is below tolerable levels.

c. Time – turn off one transmitter when another is turned on.

Obviously, these restrictions limit the number of radio transmitters that can be assigned to a particular service at a particular location.

There is another means, however, of using the same frequency simultaneously in the same location. Do not allow the signal to radiate. Keep it confined so that it reaches the receiver terminals over a shielded and a controlled path. Protect the signal from interference with or by radiated signals which saturate the air.

Physical wires offer this opportunity for a directed confined signal distribution system. The most suitable of the wire configurations is the "coaxial cable" which will be described in more detail below. While coaxial cables may not carry all of the electromagnetic spectrum, certain types can carry a sufficiently large chunk of it to accommodate all of the broadcast bands and many of the other services. The presently limiting factor is not the cable so much as associated system equipment.

Coaxial cable gives us a multiplying factor for the electromagnetic spectrum. If the incentive is great enough to "wire a city" we can reproduce our present communications capacity each time we choose to install a coaxial cable system for distribution of signal to the homes in that city. Each such cable system represents a quantum jump in our communication capability. Instead of husbanding the assignment of radio channels for a limited few, the economy of scarcity; we can now challenge the imagination and energy of programmers, service suppliers, community psychologists and educators for productive utilization of the communication channels that can be made available.

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SECTION III

EXISTING SYSTEMS

A. General

The incentive for the first introduction of the wired city was supplied, under our free enterprise system, without subsidy or without long-range planning. We stumbled into it by our need to fill a need. A community antenna service evolved to capture and distribute broadcast television signals to homes in a community in a manner better or more convenient than the individual homeowners could do it for themselves. The service proved to be easily marketable. Ingenious application of limited but available technology, the desire for better signals, and freedom of choice in program selection and a favorable cost, combined to form a new industry.

As word spread that a new "home town" business had been created more individuals with some skill and much ambition took the risk of installing systems. The market for hardware increased and by necessity manufacturers began devoting engineering effort to develop specialized equipment. Better equipment and an increasing demand for more service eventually expanded systems from 3 or 5 channels up to 7 or 12 channels. Operators soon found that unlike broadcast station allocations and contrary to "expert" opinion they could occupy adjacent channels on a single cable. Channels 2 and 3, which are adjacent in the frequency spectrum, are never licensed to broadcasters in the same area. Cable operators found that if they balanced the levels of the visual carriers and reduced the level of the FM sound carrier, commercial television sets would successfully receive signals on both 2 and 3. This one development effectively doubled the viewing capacity of the home VHF receiver. Even the largest metropolitan area (New York, Los Angeles, etc.) were assigned only 7 VHF broadcast channels. Cable viewers in many small communities have access to programs on all 12 VHF channels.

Two questions then arose. Why would a cable operator want to go to the expense of increasing the channel capacity of his system; and how would he program these additional channels. The why was the increasing competition for franchises (the local community licenses to install physical plant on public property) and the apparent expansion of market potential with expanded services. The how was by importing more distant television signals, even those beyond the range of even the most elaborate broadcast receiving antennas, using long-haul microwave and by "converting" UHF television broadcast station signals to the VHF spectrum. An example of the former is the importation of the Spokane, Washington broadcast stations across the Rocky Mountains, using several repeater microwave stations, to Great Falls and many smaller Montana communities. An example of the latter is the conversion (at the head end) of the New York City Municipal TV Station, UHF Channel 31 to VHF Channel 3. There it can be successfully received by many more people, and it has a much more favorable competitive position on the selector switch of the viewer's television dial.

The problems of regulation, copyright and competition with established media enter into the above picture. Catch words like fragmentization, piracy and non-duplication become part of the industry vocabulary. But such matters are not the subject of this paper.

A third means of "filling the channels" was for the cable operator to produce his own programming. This opened up a whole new requirement for technical equipment, skills and operating experiences. Manufacturers quickly produced some primitive but effective "automatic programmers" such as the weather channel, the news ticker, the (delayed) stock market tape. Some operators invested in inexpensive 16 mm film camera chains and sought out the cheapest feature film they could find. Here they competed with the "grind" programming of some broadcast stations. But this kind of programming was just "more of the same" and it was a capital burden since there was no advertising income to support even these modest costs. Where good product could be run in areas where there was not enough broadcast fare to provide a choice of "escape" programs, film features were accepted and are used.

The really new service of cable came from those operators who had the skill, foresight or competitive need to provide "local event origination." Here is a service that even the smallest broadcaster with his many thousands of square miles of coverage cannot provide. Here is a service that the cable operator has both the channel capacity and the distribution directivity to do well. It converts television from a mass interest media into a minority interest media. And so local origination, with its related regulatory invitations, competitive turmoil, new skill requirement, additional investment needs and potential labor problems come into being.

Filling the channels was so successful and an increasing demand was so insistent that operators soon suspected that more than 12 channels would be required.

As the needs, potential and magnitude of this new industry are increasingly understood, the requirement for hardware and specialized design is attracting the interest of many competent engineering and manufacturing firms. Some of these are investing sizable capital in studies of the market and in product development. This may seem a paradox at a time when regulatory restrictions, delays and uncertainty on pending legislation and control has severely limited new system starts. The production planning and engineering programs of established CATV equipment suppliers has been seriously curtailed and substantial personnel cuts have been imposed.

One ingredient not discussed above has influenced the existing technologic pattern and future development of the industry. This is the evolution of the Multiple System Operator (MSO). Towards the end of the '50s some of the single system owner/operators began to expand their own group of cable holdings or to sell their systems to other operators. This extended base of operation permitted more dollars to be devoted to system planning, professional engineering, purchasing control and centralized accounting. Today, the largest of the MSO's serves less than seven tenths of one percent of the national television homes; a fraction of the homes covered by just one broadcast station in a major market. But even this small broadening of the base of operations has provided the means for evaluating the true potential of cable communications.

B. System Description

A system manager must have many talents. In a small system he is administrator, technician, salesman, community friend and booster, politician, right-of-way negotiator, trouble shooter, complaint solver, and bill collector. In larger systems he can afford some staff to assist in these problems. In multiple system organization he can call on specialized guidance, for his implementation, in each of these categories. Most cable operators are members of the National Cable Television Association (NCTA) where they have access to advice, guidance and data relating to their problems and to the interests of the industry. The annual national convention and many regional meetings provide management and technical papers and attract impressive product and services displays.

A typical operating plant consists of:

a. The Head-End.

b. The Distribution System.

c. The Home Terminal.

Each of these facilities will be described here.

1. The Head-End is the programming source of the system. All of the head-end functions are frequently but not necessarily located in one place. Although there must be one feed point for the total signal to the distribution network, sources of signal may be separated as a matter of convenience. Broadcast receiving antennas are located at an optimum receiving spot. This means away from local industrial noises and interference and at a favorable elevation, either natural terrain or a tall tower, for better or more distant signal reception. Usually individual antennas are used for each channel for maximum gain and directivity. This permits orientation of the receiving antenna beam directly towards the transmitter. Sharply tuned antennas, however, are avoided if they give band pass problems detrimental to the signal reception. Some operators have attempted very long distance (scatter) reception by use of huge parabolic structures requi[illegible] a half acre or so of ground.

Obviously, it is sometimes beneficial to install antennas at different physical locations to take advantage of natural terrain. Weak signals are sometimes "boosted" right at the antenna terminals by "pre-amplifiers" suitable for the channel being received.

Most operators include antennas and equipment for receiving FM broadcast stations. Since the FM band is located in the 20 MHz segment of the spectrum immediately above TV Channel 6, it falls well within the distribution handling capacity of most cable systems.

Distant reception is more frequently obtained with the aid of microwave relay links. Indeed it was because of the use of microwave relays that the FCC first asserted its control over cable systems. A broadcast receiving antenna location is established within the good signal reception area of a station. This signal is demodulated and the video and sound are multiplexed on a frequency modulated microwave carrier. Initially, the Commission licensed cable operators in the 6 MHz microwave band where equipment was well developed, not too expensive, and where propagation characteristics for long distances were favorable. In 1965 CATV operators were given notice to vacate that band unless they could qualify under the 50% common carrier rule. This meant that 50% or more of the cable system channel hours of program carried on the link must be used for the benefit of systems that were not owned or controlled by the microwave operator. Lacking that criteria, the operator was given a reasonable period of time to convert his link to the Cable Antenna Radio Service (CARS Band) in the 12.7 to 12.95 MHz region. This same microwave band has now been authorized for Local Distribution Service (LDS) for cable operators, describer in a subsequent section.

Microwave links can be repeated if necessary depending on the terrain and the distance -- preferably through heterodyning repeater stations. The final receiver, at a cable head end, must demodulate the video and sound and then modulate these program signals in the form suitable for a conventional home television receiver.

Repeated modulation/demodulation processes contribute most of the degradation of cable signals due to differential phase, differential gain and group delay. Such problems will continue until better "modem" techniques or equipments are engineered. Normal broadband cable systems which distribute two or more octaves of VHF frequencies without modulation/demodulation (modems) do not introduce these kinds of distortion.

Locally originated programs, of course, require modulation but this is a once only process which is equivalent to the original transmitter modulation of a broadcast station, without the high power complications. Originally, cable originations were strictly "poor boy" operations, using minimum equipment and operating skills and resembling a small school ETV facility more than a broadcast station. Still, it is surprising what interesting programs - perhaps interesting only to that local community - have been produced by these minimal facilities. Now, as cablecasting becomes an increasingly important part of the operation - required by the FCC (as of April 1971) for systems having over 3,500 subscribers - and particularly with advertising or channel leasing hopefully to relieve the burden of facilities cost and operation - the equipment is already becoming more sophisticated. The studio equipment manufacturers are now offering third or fourth generation camera designs. Comparatively low cost items can produce results equivalent to the broadcast quality of only a few years ago. For example, several manufacturers now offer color cameras in the ten thousand dollar range which, considering the average operator available to cable TV, may produce better pictures than a 60-thousand dollar network instrument.

Cable systems universally use "slant track" video tape recorders with good results but suffer from lack of standards in this equipment which permits interchangeability of tapes on different machines. Naturally it is expected that if cable networking reaches regional or national proportions, some programs may originate from existing broadcast studios or from studios that are equivalent to the broadcasters in equipment and personnel. Such professional origination facilities have been used many times in the past for theatre television presentations and for industrial closed circuit programs. The trend, however, is to keep programming costs low so that more programming per dollar will encourage greater variety and community access to the multi-channel distribution system.

Automatic programming will continue to occupy channel space but with greater design thought given to performance, display readability and viewer interest.

An important head-end function is signal processing. This means the assignment of channel space to each program, balancing of video carrier levels and the adjustment of the sound carriers for adjacent channel operation.

The locally originated signals and video signals delivered by long-haul microwaves achieve this balance in the modulation process. Crystal controlled oscillators are used for selection of the assigned channel. UHF stations and VHF stations are generally not demodulated but are converted to an intermediate frequency (IF) where a band pass filter cuts off out-of-channel signals. This circuit separates out the sound carrier, permits independent video carrier and sound carrier level adjustments, recombines the carriers and finally translates the I.F. back to the assigned VHF channel. Note that the output channel can be, but is not necessarily the same, as the input channel. UHF channels, of course, must be converted to VHF frequencies to be carried over the distribution system. (UHF carriage on frequency is discussed in Section II). Even VHF stations are sometimes given new channel assignments for an interesting technical reason. This channel change can, of course, be upsetting to the broadcaster who promotes his channel number identification and originally confusing to the viewer who finds that his local Channel 7 may now come in as Channel 12 on his tuner dial. The reason for such a channel shift is to avoid interference between two stations which broadcast on the same channel or between a locally transmitted signal which is so strong that it leaks into a viewer's television receiver. There it interferes with the signal of that same station delivered to the antenna terminals of that some receiver over the cable. Such interference produces an unwelcome "leading ghost" type of interference. Changing channels at the head end avoids this off-air interference but means that the channel of the strong local signal is left unoccupied on the cable. In an area close to the Empire State building transmitters in New York City, seven channels would have to be left unoccupied for this reason. At a time when there is an increasing demand for channels such waste is unthinkable.

Obviously, the problem would not occur if the home television receiver were leak-proof, i.e., shielded well enough so that it would not pick up signals except those delivered directly to its own antenna terminals. While this is straightforward design it would have added a new element of cost to receivers and has been rejected by the set manufacturers.

The cable operator solved his problem by building his own, well shielded channel tuner and providing it to his subscriber as part of the cable system. This device performed the same function as his head-end converter, changing a channel being supplied by the system to some channel which has no interference from strong off-air signals. With such equipment not only can all 12 VHF broadcast channel assignments be used but non-broadcast channels in the "mid" and "super" (see Table I) band can be selected and converted to a channel useable on the viewer's set. Such converters now supplied in a New York City system have a 25-channel capacity. Channel number identification is no longer a problem since the converter dial can be labelled by the system operator to conform. The viewer also has the convenience of a remote tuning control which can save him a few steps when he selects his program material. These benefits are beginning to justify the cost (approximately $40. installed) of this device at each subscriber's terminal.

The head end provides a point of system programming control. It is here that the non-duplication rule, imposed by the FCC for the protection of local broadcasters, can be implemented. The program on a more distant broadcast station which "duplicates" a program on a local station can be "blacked out" -- removed from the cable. This function requires somewhat elaborate pre-programmed equipment to control what time segments on what stations must be removed from the view of the system subscribers. If proposed rules which require deletion of certain commercials from distant stations are implemented, this program content censoring equipment will become even more elaborate and involved.

Community emergency services also require head-end equipment. The Liberal, Kansas system, for example, has installed a microphone and cut-out switch at the Chief-of-Police office. Operation of the switch allows the Chief to temporarily insert his voice on all cable sound channels -- to give tornado or other emergency warnings.

The final process of the Head End is to combine all of the spectrally distinctive signals onto one cable at the right signal level and to feed these signals into the distribution system.

2. Distribution -- The distribution network includes the cable and all the oppurtenant devices necessary to carry the signals from the head-end to each of the subscribers terminals. A cable system is a gigantic party line with every one connected to the same wire circuit. It is a tree network where the product from the root is carried through the trunk and then the branches to the individual stems which feed each individual leaf. Historically, CATV systems have been one-way transmission but recent developments are so important and offer so many opportunities for public benefit that the whole new art of two-way broadband cable communication will be treated in a subsequent section of this report.

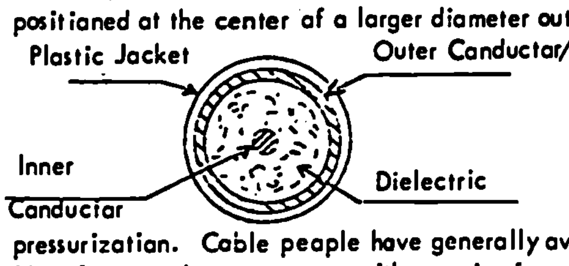
a. Cable -- It is well known that electrical currents can be carried along wires. Current flow and electrical potential also set up magnetic and electrostatic fields that do not require conductors but can radiate through space. Energy on a conductor is lost by radiation and by absorption due to the work necessary to push electrons through the conductors (resistive losses) or to push concentrated fields through non-conductive materials that occupy surrounding space (dielectric losses). These factors constitute the losses of a wired system, usually expressed (for communication signals) as the logarithm of the ratio of the power into a system compared to the power measured at some point along the system. This "attenuation" of power is measured in decibels, a unit of measurement usually shortened to the symbol dB. Three dB represents a 50% loss in power. Cable losses increase as the frequency of the electrical currents increase.

Physical configuration of the conductors influence the characteristic impedance of a transmission system which in turn determines the interrelationship of voltage and current and, consequently, of power. Abrupt or radical changes in characteristic impedance cause reflections of power which can result in additional losses, ringing, frequency sensitivity and other disagreeable effects. Thus, the cable itself must be uniform and any transitions in the cable, such as connectors, and all terminations including equipment inputs/outputs must be matched "or transformed" to a new impedance level. Characteristic impedance of a transmission line is generally insensitive to frequency.

Electrical power (direct current or 60 cycle typically) can be carried on conductors of almost any configuration. Radiation and dielectric loss is no problem but heavy currents make resistive losses important. Telephone voice circuits and telegraph circuits are also low frequency, and since very little power is involved, can be handled by small "twisted pair" conductors with minimum insulation and tight physical space. Thus, telephone trunk cables of many hundreds of pairs (one pair for each anticipated telephone terminal) can be compacted into relatively small cable diameters. Normally, twisted pair telephone circuits are designed for about 3,000 cycles of voice communication. Even these circuits needs some "equalization" to balance the levels of the higher frequencies with the lower frequencies. More elaborate equalization and amplification can extend this transmission band to 8,000 cycles or above. Being unshielded, normal telephone pairs are subject to cross talk and radiate at higher signal frequencies. More than one telephone terminal (extensions and party lines) can use a single pair on a shared time basis.

Coaxial cable is a conductor configuration particularly suited to high frequency transmission. Such cables are used to transmit electrical signals from zero frequency (direct current) all the way up to several thousand million cycles per second. For practical purposes, long runs of modern polystyrene foam cable are generally not used at frequencies above 300 MHz. While the useful bandwidth of a CATV coax could be said to be 100,000 times that of a 3 KC phone line, the real truth is not as direct as the arithmetic solution indicates. Nevertheless, assuming suitable amplifiers (which we do not yet have) it may be possible that 40 standard TV channels of 6 megahertz bandwidth might be carried on one cable.

The word "coaxial" comes from the fact that a small diameter inner conductor is positioned at the center of a larger diameter outer conductor. (see figure). Ideally, the space between the two conductors would only be occupied by air but since this is physically impossible, plastic spacers such as discs or helical ribs are used. Such open spaces make effective water traps and in exposed locations require line pressurization. Cable people have generally avoided that added cost and maintenance. Manufacturers have come up with superior foam dielectrics, plastic enclosed air cells. This is a structure which has physical strength and is an effective block to water penetration or transmission. The attenuation of some of the foam cables has begun to approach the low value of a true air dielectric coax.



Originally, the outer conductor of coax cables was made of copper braid. This was flexible and generally available, but did not provide a suitable weather seal. In strong ambient signal areas it did not provide sufficient electrical shielding. Again, the manufacturers provided the answer with a solid aluminum outer shield/conductor made by extrusion, seam welding or by a sealed lap joint. Even the small diameter "house drops" are now generally shielded with a solid metal (generally an aluminum foil with a lap joint) outer conductor and "drain wires" or a loose braid.

Most cables have a tough outer jacket of polyethylene, with a high molecular weight carbon loading, for environmental protection. In some climates, aerial cable plants do not need the jacket and the metallic aluminum gives better thermal protection than the heat absorbing jacket. Some underground cables include a very viscous material between the metallic shield and the outer jacket. This material acts like a puncture proof gas tank, sealing any cuts or nicks. In certain areas of the country a steel armour is necessary to protect underground cable from rodent type animals.

The cable industry generally uses four sizes of coaxial cable, all sizes having 75 ohm, characteristic impedance determined by the dielectric and the diameter ratio of the outer and inner conductors. The sizes generally identified by the diameter of the unjacketed outer conductor are "750", "500", "412" and RG-59/U. These are 3/4 inch, 1/2 inch, 27/64 inch and approximately 1/4 inch diameter respectively. The larger the diameter the less the loss of the cable, the fewer amplifiers required (or the longer cable lengths for a given number of amplifiers) and the more difficult the job of installation. General practice is to use 1/2" or 412 for "trunk" line, 412 for "feeders", 59/U for house "drops" and 3/4" for super trunk runs.

The backbone of the system is the trunk. This cable carries signal from the head end to the extremities of the area served with the minimum possible number of amplifiers (generally 3 to 4 to the mile) and no subscriber taps. Bridging amplifiers (see below) may provide junctions to sub trunks or to feeders. Feeder cables are comparatively short runs which may parallel the trunk either forward, by doubling back from a junction or branching off to serve a local area. Feeders can branch to sub feeders using passive splitters or directional couplers and "line extender" amplifiers. Subscriber taps are put only on the short feeders, to avoid the cumulative effect of these discontinuities on the trunk line. Drop cable, rarely over 150 ft. in length, carries signal from the tap right to the subscriber's terminal in his home.

The Super Trunks are generally reserved for long "cross country" runs without subscriber potential, such as carriage of signal from a receiver tower to a central office.

"Aerial Plant" refers to cable that is suspended in the air on poles. These are usually telephone or power poles but in rare instances cable companies have been permitted to set their own poles in certain areas. Unless the cable operator is the local telephone company, or has obtained a "lease back" (a long term contract where the phone company installs and maintains the cable plant under tariffs related to number of channels, types of carriage and miles of plant) he must negotiate a pole line contract. The Bell System companies have now agreed to make their poles available to cable operators. The procedure, after executing a contract, is to specify the plant, identifying each pole by number and location. The phone company inspects each pole and writes an engineering order specifying what "change out" (modification) is required. Telco personnel make the changes. The poles are then available to cable operator personnel or his contractor to install the cable system. These contracts involve a change-out charge and an annual rental fee for each pole.

The coaxial cable, trunk and feeder, is "lashed" to a steel "messenger" cable which provides the physical strength in tension and carries the weight of the coax and some of the equipment. Expansion loops or "S" bends generally located at splices or equipment points further relieve strain and allow for thermal expansion/contraction of the metal. Need for assorted plant hardware and special vehicles for installation and maintenance provide a good market for suppliers of those items.

Underground installation is frequently used and is becoming increasingly popular with cable operators. It is more expensive and requires greater cooperation and coordination with departments of the local government but it has many compensating advantages. It greatly improves the appearance of the community; it removes dependence on obligation to or unavoidable delays of the telephone company; it provides thermal protection (smaller variations in cable temperature) and eliminates danger of ice storms, wind storms and reckless drivers. Tools, such as the self propelled vibrating plow and flexible shaft boring equipment make the job easier. Substantial improvements in underground techniques are expected as the need is recognized and the market increases. Much underground plant is "direct burial" but some believe that the additional cost of plastic pipe is a wise investment for cable replacement or system growth. Small underground vaults of concrete or metal, having lids flush to the surface of the sidewalk or grass (painted green), house the system equipment and taps. Many installations house equipment in shrubbery concealed snorkel pipes which extend above ground. Naturally, all such installations must be fully protected from flooding. A great aid to this is the development of heat shrinkable tubing which can seal connectors and housing entries.

b. Amplifiers are the electronic circuits which are inserted in the cable to compensate for the losses of the cable and other passive devices on the cable network. Early amplifiers were all vacuum tube designs and frequently required separate circuits for each TV channel on the cable (strip amplifiers).

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More often one circuit would amplify the low-band (channels 2 through 6) and a separate amplifier would amplify the high-band (channels 7 through 13). These circuits required much electrical power, generated heat in their weather-tight enclosures and required much maintenance in the form of tube replacement and continuous rebalancing.

In the early '60s one manufacturer introduced a broadband (channel 2 through 13) solid state (transistors and printed circuit board) type of amplifier which was risked in a system by one of the MSO's. After much scoffing, initial industry resistance and a certain amount of "debugging" this design revolutionized the industry. This new market interested the transistor manufacturers and provided an incentive for more rapid development of improved solid state components for the VHF frequency range.

Now, an equally revolutionary design change is beginning to take place. The rapid and recent growth of thin film, thick film, MOS and other techniques that are still strange to the tongue as well as to the understanding, may find a natural application in broadband cable communications.

Amplifier designs now generally in use have a useful band from 54 MHz to 216 MHz without gaps. They are normally rated for use with the 12 assigned broadcast TV channels 54 to 88 MHz, and 174 to 216 MHz; and for the FM band 88 to 108 MHz. Some manufacturers and operators have tested these amplifiers for mid-band carriage, 108 to 174 MHz. Some, but by no means all, of the present amplifiers can be operated with up to eight additional mid-band channels at a cost of reducing output levels by about 3 dB and limiting the number of amplifiers in "cascade" (connected in a string on one coax line) to about 25 or 30 rather than the usual 50 or more. This means that only the most modern and best equipped systems now operating have a possibility of extending their channel capacity to as much as 20 channels. All of these extra channels will be in the mid-band since high end cut-off was always just above Channel 13 (216 MHz).

Early 1969, however, most manufacturers saw the growing demand for more channels and began examining their designs for extending their channel capacity. It was not too hard to extend the upper cut-off frequency, using improved transistors, but the interaction of the visual and sound carriers (the nature of cross modulation and beats is discussed later) is a matter of great concern. Some considered use of multiple single octave amplifiers which would avoid some of the problems. Many decided on upgrading their amplifiers from single ended circuits to the more costly push-pull stages which suppresses second order distortions. All attempted to achieve greater amplifier linearity. Non-linear circuits are the chief villians responsible for generation of unwanted spurious signals.

Equipment salesmen and market planners started playing the numbers game. If one company said 20 channels, another said 24 or 27, or 32 or 36 or 40; take your pick. The engineers and designer are having a hard time keeping up. Certainly, system operators have not had sufficient field experience with these new equipments as yet, even with dry-run or test signals, to evaluate performance or to determine the nature or magnitude of co-related problems.

But the desire is there, the effort is being made, design and field testing money is being spent. Engineering competence exists to achieve the kind of channel capacity required. The unknowns are time and money. Many operators know that they may be able to extend their present distribution amplifier systems above 12 channels to 14, perhaps to 17, and some even to 20 -- if they are willing to make a substantial investment in subscriber terminal converters. Beyond that number, however, they will undoubtedly require new plant construction and/or amplifier replacement. Fortunately, in most cases, at least, the cable itself will be able to accept the additional channels without change.

In addition to the bandpass and channel capacity of amplifiers, there are other important operating features and performance criteria. The "noise figure" of an amplifier is a measure of its contribution of random unwanted thermal signals spread across the frequency band that in the extreme condition is known to the viewer as "snow." The level of input signal (how low it can get before being amplified) and the level of output signal (a function of input level, gain and linearity characteristics) determine what length of what size cable can be placed between amplifiers. The number of amplifiers in cascade reduces the tolerance of the values of input and output levels until the adjustments become so critical and sensitive to environmental changes that quality performance is no longer possible. A current rule of thumb limits cascades to about 50 trunk amplifiers (some manufacturers say 80) at a spacing of about 3.7 amplifiers per mile of 1/2" cable. This indicates practical trunk limitations of 14 to 20 miles along different radials from a point of head-end signal insertion.

It has already been mentioned that cable loss increases with frequency. Loss in a system at Channel 13 is more than double the loss at Channel 2. Therefore, all amplifiers have a "slope" gain control as well as a "block" gain control. Unless proper slope is maintained cumulative effects can cause substantial unbalance of the channel levels at the subscriber's terminals.

Level adjustments are aided by "AGC" (automatic gain control) which helps to compensate for cumulative effects of cable loss or due to changes in an amplifier gain because of component aging or different power voltages. This control is aided by one (or sometimes two) reference "Pilot" tones inserted into the system at the head-end. The purpose of AGC is to maintain a constant output level for a range of input levels. Normally, about every third amplifier in a system has an AGC circuit.

Special temperature compensating circuits help to reduce the load on AGC. Changes in temperature change cable loss - higher temperatures mean greater loss. The compensating circuits are designed to have the opposite temperature characteristic -- less loss with higher temperature. Seasonal changes generally require manual system reb ncing by an operators maintenance crew but hourly changes, particularly hot days and cold nights as in some areas of the Southwest, require special attention to automatic control. Underground systems, protected by the insulation and the thermal lag of the earth, have far less critical temperature adjustment requirements.

Lightening damage to plant is a matter of serious concern. Direct hits are not needed; induced currents or surges carried by power lines or the cable itself can burn out sensitive solid state components. Whole branches of amplifiers have been damaged by one lightening strike. Of course, the heavy metal of the cable shield and equipment cases does give protection if grounded properly and frequently. Drain wires, spark gaps, and surge protectors in the equipment circuits help reduce this danger of service outage.

Not all amplifiers have the critical performance requirements of the "trunk" amplifiers. "Line extender" amplifiers, where only a few units are operated in series on any one line, take advantage of this more modest requirement, particularly in areas closer to the head end, to help reduce total system cost. Many operators, however, are beginning to think that this is false economy. Now that system performance criteria and increased loads are apparent, the line extender amplifier may be the first that have to be replaced.

"Bridging" amplifiers in trunk or feeder lines have good performance characteristics. They differ from trunk amplifiers in that they may (or may not) have very little effect on the main trunk signal but have multiple high level feeder outputs, isolated from the main line.

c. Passive Equipment -- This type of line equipment does not provide any gain or amplification to the system signals although some passive networks are included in the active devices that were described in the previous paragraph. The passives require no electrical power. They divide, split, add, isolate, reject, or discriminate as to the direction of flow. Most often these operations are performed on the basis of power over the full signal range, sometimes on the basis of frequency. Even those that operate over the full band are frequency sensitive. The manufacturers generally did not extend the effective range of operation of these devices beyond the limits of intended use. Therefore, many of the passives installed to date have poor or at least uncertain performance for the extended band systems that are now contemplated. Many of these items may have to be replaced in existing systems that plan to up-grade their service. Although the cost of these items is modest the quantity is large and the installation labor input is substantial. In the last two years the manufacturers have been offering, and many of the newer systems or extension of older systems have been installing, extended band passives.

Passive devices generally employ lumped components -- ferrite rings, coils, condensers, even resistors, and frequently have critical or proprietary physical configurations of these components. Of importance to the system designer is the "insertion loss" (how much power is lost as the signal passes through the device); the "match" or "return loss" (that is, how well does the device properly terminate the characteristic impedance of the cable at each of the connection points); and the "isolation" (the effect of a disturbance or unwanted signal at one output port, upon the signal at another output port).

Physical characteristics such as shape and size, environmental protection, mounting hardware, ease of installation, and cable connections are important for all line mounted items, actives and passives. Extensive design thought has been given to cast metal boxes; water tight seals; plug in circuit boards or components suitable for replacement without removing the container or the cable connections; and ease of maintenance, test or adjustment while the technician is hanging onto a pole, at the top of a ladder or working in a "cherry picker" bucket. Improved tools and techniques are rapidly developing. Great opportunities for design improvements, mechanical as well as electrical and for installation devices as well as plant hardware not only exist in this young industry but are being actively exploited. Particularly the MSO's are seeking means of encouraging new installation techniques for lower cost and less maintenance. The vigor of the industry, unencumbered by rule books, standard practice mannuals and mass but routine training classes, and sparked by fresh ideas from many sources and interested new disciplines, can not help but generate better ways of doing things.

The MSO is mentioned here because his operation is large enough and his contact with the user is intimate and vital enough to determine a need for a new device. If he decides to implement a solution for that need he is a large enough customer for the resulting hardware to encourage a manufacturing run by a supplier. Manufacturers are not used to having a built in mass market for a product where most of the risk of determining the need is borne by the customer. This happy situation, spurred by competitive interests, greatly accelerates the growth pattern of developing services such as are offered by broadband cable communications.

The common types of passive devices have been suggested above. Splitters (which are "adders" when used in reverse) divide the power from a single cable, equally (or unequally) between two or more output cables. These devices should have minimum insertion loss but maximum isolation between output "spigots". A tap sometimes called a "subscriber tap" is a form of a splitter. Its purpose is to "tap" a sufficient (generally very small, like 1/50th of a microwatt) amount of power from a feeder cable to adequately serve a subscribers commercial TV receiver input. Early systems used the simple pressure tap, a small probe inserted into the dielectric of a feeder cable, sometimes with an isolation resistor. But these were characterized by bad mismatch and no discrimination between direction of signal flow. In small systems these were tolerable and they were cheap. In large systems something better was demanded. The directional coupler was then developed for cable systems. This device is designed for low insertion loss, variable tap-off ratios (depending on the power level at the tap point on the feeder cable) and greater isolation of return signals. Special effort is made to "match" input and output terminals. Designs accomodate one, two, or four taps at a single coupler. A four tap is commonly used, placed on the line at a point to correspond to the common intersection point of four home lots. Some operators only place a tap on a line after they have sold a subscription; some anticipate a "penetration" (percentage of actual subscribers to total potential users) and install that tap capacity during the initial installation. Of course more taps can be added as needed, possibly requiring additional signal amplification but without any change in the basic cable installation. A Drop Cable to serve a subscriber is generally not installed until a sale is made but once installed is left in place. A "disconnect" is made by removing the drop from the tap and terminating that output of the directional coupler with a matching impedance.

Matching the line has been stressed repeatedly. It is important not so much because of the power loss but because a small mismatch at each end of a cable or periodically at points along a cable run will cause "ringing" (which can appear as repetive ghosts in a video picture) or "dropouts" (which sometimes remove certain specific frequencies from a normally broadband system). Before cable suppliers realized the effect and took steps to remove the cause, the mechanical process of manufacturing cable sometimes introduced periodic irregularities (for example, a small nick or dent in a conductor every time a wheel in a machine made one revolution) which "sucked out" a TV channel. Now cable is "swept" over a specified frequency range as part of quality control.

Cable connectors are an important but seldom recognized passive device. Thousands of connectors are used in a system – to splice two ends of cable or to attach cable to some item of equipment. They represent a percentage of total system cost and each connector offers an opportunity for mismatch, water penetration or signal leakage. More than one cable operator has traced complete loss of signal on a portion of his line to a connector, installed in the summer, when cold winter temperatures contracted the inner conductor of his cable and pulled it right out of the connector center pin. New simpler and better connectors are now being designed and tooled.

d). Power Supplies

At one time every amplifier had its own power supply and had to be connected to a source of 120 volt 60 cycle power or similar conventional source. This was not inconvenient at the head end or at a subscriber terminal but it imposed serious difficulties for amplifiers on pole lines or in underground vaults. Even "power poles" often carry feeder (high) voltages and not house power voltages. Almost all cable systems are now cable powered. The coaxial cable itself provides the conductors over which operating power is brought to the active equipments on a cable system line. Thus electrical power can be inserted onto the cable at much more convenient spots. It is often fed, generally at about 30 volts, 60 cycles, (some equipments may use as high as 60 volts, depending on applicable codes and real or fancied design advantages) both up and down the cable for as much as two miles in each direction, to supply all of the active equipments on that section of the run. The cable must have sufficient metal in its inner and outer conductors to carry the power currents without undue loss. Thin foil or film conductors which might be suitable for the VHF signals would not carry sufficient cable power to serve a modern system (nor would such thin films offer sufficient lightening current drainage). Naturally each item of equipment along the line, active and passive, must pass or block transmission of power on the cable at the discretion of the system designer. Blockage of power is necessary to isolate one power source from another source further down the line. Direct currents are not used on the cable because DC greatly increases the possibility of electrolyte corrosion at junction points. Each equipment item must still convert this AC supply into DC and provide the necessary levels and regulation for its own circuits. Solid state equipment which uses little power and likes low voltages is particularly suited to the cable powered practice.

The question of emergency power for cable systems has started to be a matter of increasing concern as more vital or commercially valuable services are rendered. Some operators have installed emergency trickle charge battery packs and inverters at power points which have difficult access or where power service is notably subject to failure but this practice is rare. With expanding services, operators who argue that a power failure in a neighborhood also disables the home television receivers and therefore the need for cable service may have to look for other excuses. Nevertheless an emergency power standby at the head end and at critical line points or terminals could represent a major item of additional system installation and maintenance cost.

3. Home Terminals:

The consumer of the services supplied on the cable is primarily the family in the home. That residence may be a house or an apartment and is more generically referred to as a dwelling. A far smaller percentage of total outlets are installed in hotels or motels, stores that sell television appliances and in bars or restaurants. Connections are also made to schools, hospitals and institutions and municipal buildings such as police or fire stations.

Since September 1968 home installations of cable have been covered by a new section (Section 820) of the National Electrical Code published by the Board of Fire Underwriters. The section is titled "Community Antenna and Radio Distribution Systems." While the code requires certain logical practices which increase an operators cost, such as a grounding block near the home or group building entry, it is more permissive than demanding. This section is helpful to the industry in that it formally recognizes CATV wiring. It covers the installation officially rather than leaving the interpretation of more general or less applicable codes up to the discretion of local inspectors. A copy of the code is attached as Appendix I. Canada has a similar code, published prior to the one in the states.

a). Cable Drops

Cable into the home brings a variety of problems. Drop cable was originally the government specified cable designated RG-59/U. This was the only small diameter, 75 ohm characteristic impedance, coaxial cable readily available on the market. This black jacketed, quarter inch diameter cable has five or six times the attenuation of super trunk cable but it is used for a short runs. Its non-cumulative loss actually becomes part of the intentional isolation inserted at the tap. The original RG-59/U has now been modified by the industry. Foil wrap rather than braid outer conductors, foam rather than solid dielectric and thinner jackets in a variety of colors are now being offered. An even smaller diameter l greater loss cable for exposed wiring is being contemplated.

Messenger supported aerial cable from a nearby pole or a plowed underground run from a tap box brings the cable to the home. Some drop cable has a built in messenger in a so-called "Figure-8" jacket. The cable enters the building generally above ground, with drip loops, plastic sleeves, strain relievers and other means of weather and mechanical protection. A grounding block or other electrical connection ties the outer conductor of the cable to a house ground (metal water pipe or the equivalent). One (or more) outlets are located at points selected by the customer. Sometimes this means boring through floors or walls or running the cable along baseboards or around doors. Since quarter inch black cable is not an interior decorators delight, inside cable is now supplied with jackets of off-white or beige. In especially critical homes some operators have actually hand wrapped cable in matching wood grain adhesive vinyl. Customer relation conscious operators have neat appearing installers, often in uniform, and even supply small hand vacuum cleaners to tidy up the mess.

The cable sometimes terminates in a wall box but more often it is dressed right to the television set antenna terminals. Receiver inputs have always been 300 ohm balance parallel wire connections. While this may have been a convenience for home antenna installations it now seems a poor choice. It provides little or no shielding, and requires internal conversion to accommodate unbalanced circuits in the set. It does not match the impedance of the unbalanced 75 ohm coaxial cable. Although frequently brought to their attention, set manufactures have steadfastly resisted an input change. Thus the cable operator provides the necessary matching transformer a balun (balanced to unbalanced)transition, generally placed right at the input terminal of the set.

It has been an unwritten rule that except for the external operating controls, cable operators do not touch or modify the customers receiver (although there have been some exceptions). There are two reasons for this. Operators have not wanted to compete with or alienate the local TV repairman or TV set dealer. Second, they have found that as soon as they take the back off the set, the responsibility for the performance of that set often becomes theirs. Some customers feel that if a kinescope burns out or a condenser blows the cable installer must have done it and ought fix the set at his expense. Of course any terminal equipments supplied by the system are and will be the operators responsibility. It is a recognized added cost of doing business that the cable service office is usually called first regardless of the problem. The time, travel and reporting of a service call costs an operator in the order of ten dollars per trip, even for false alarms. If a problem can't be pinned down to the set over the phone, a service call is made. Maintenance men carry portable sets in their trucks and use this advantageously to prove that the customers set and not the cable is at fault.

b). Converters:

The converter is an increasingly common item installed at the subscribers terminal. This is an expensive piece of active equipment and requires local electrical power. Converters were mentioned above during a discription of the head end. With the growth of the industry and cable services there have been an increasing number of reasons for having this kind of equipment at the subscriber terminal rather than at the head end.

A subscriber converter is actually a well shielded channel tuner having a 75 ohm coaxial cable input. Ideally this device should simply by-pass the tuner in the subscribers television set and have an I.F. output suitable for directly connecting to the intermediate frequency stage of the receiver. It is possible that some enterprising receiver manufacturer might supply a color set without a tuner, having only an I.F. input terminal. Since we have not arrived at that sophistication as yet, and since the cable operator does not choose to modify his customer's receiver, the present converter designs include another stage. Its I.F. signal is reconverted to a standard VHF Broadcast channel and delivered to the set. The set tuner now selects that converter output channel and again translating it to an internal intermediate frequency. This means at least two unnecessary interface stages and about thirty dollars of unnecessary expense (the set tuner and the converter output) jointly borne by the subscriber and the operator.

The converter performs four functions:

a) Protection against interference of strong local signals due to poor shielding in the receiver. This function was provided at the head end until the demand for 12 channel systems become popular.

b) Extension of the capacity of the home receiver, beyond 12 channels. The tuner is no longer limited to the channel frequencies allocated by the FCC to broadcast services. Converters now supplied as standard equipments in Manhattan system have 25 channel capacity.

c) Remote tuning control. The converter and its channel selector can be located across the room from the TV set, permitting arm chair tuning.

d) Positive channel identification both as to channel number and to selector switch position.

c). Multiple dwelling wiring:

Wiring in dense urban areas and multiple dwelling buildings anywhere offer special problems. Particularly the landlord problem and the access problem are of concern here. Briefly this relates the difficulty of refusal or exorbitant demands by building owners for permitting cable services to be provided to residents in their own buildings or even for right-of-way for cable passage across their property to serve other people and buildings in the same block. The right of "eminent domain" or "police powers" or other brute force methods have never been tried and may not be applicable. So far CATV services are not vital or essential and reprisal measures such as might be suggested by the utilities or telephone services are not effective for cable. The access problem is a serious one resulting from the practice of following electrical contractor wiring methods rather than communication services methods for installation of Master Antenna Television (MATV) in apartment buildings. /1 The major difficulty here is that system wiring is located behind locked doors, subject to abuses which cause service disruptions or malfunctions but not available for repair or control of the service operator. New methods of wiring the buildings and methods of inserting cable into sidewalls for by-passing buildings have been thought out. These methods cure this problem but the new practices must be "sold" to owners, building trades people and to city departments.

/1 MATV systems provide a common antenna and cable connections for tenants of a particular building. Low cost and conventional construction trade wiring methods has been governing criteria for these installations.

C. System Performance

The design problem for layout of todays CATV systems is comparatively straightforward. The daily problems of making everything work together, finding troubles and solution to those troubles requires understanding, knowledge, patience and dedication. System design is largely a problem of acquiring good video signals or R.F. signals; selecting head end processing equipment which adds a minimum of signal degradation and spurious signals; and then performing the arithmetic of cascading trunkline amplifiers.

1. Broadcast reception. Good broadcast reception of a large number of channels requires skill and luck. Even with the best equipment, tower location and propagation paths, so-called studio quality is an impossible dream. There are many variables over which the cable operator has no control - the program content; the technical excellence of the program source (AT&T long lines, film, tape or the broadcasters studio camera); the performance of the transmitter; the transmitter power; the propagation distance; weather; and some multi-path situations. Surprisingly often the cable operator receives the blame for these factors.

Co-channel interference (two broadcast stations on the same channel) plagues the cable operator because the FCC channel allocation plan was conceived for the average home owner with his rooftop antenna rather than a super antenna on a high elevation or 200 ft. tower. Co-channel produces the familiar "venetian blind" effect resulting from a beat of two carriers slightly off frequency, or by a faint image picture superimposed on the primary picture.

There has been much talk about improved picture quality by taking direct video feeds from local stations, avoiding the R.F. transmitter/receiver stages. Some day we may reach that degree of sophistication, but it is not done now. The mere mention of the possibility horrifies the copyright lawyers and regulatory bodies. The broadcasters are torn between a desire to deliver better picture quality for their channel and an inherent reluctance to cooperate with a possibly competitive commercial enterprise.

Site selection, with considerations of zoning, real estate availability, local interfering signals, roadway access and power availability and reliability, requires money, patience, time and often good local politics. Receiver site selection offers many opportunities for second guessing - regardless of where you are there is always a possibility that it could be better.

Headend processing equipment and selection, performance and maintenance is totally the cable operators responsibility. Here, and perhaps also in the site selection, he is guided by what is available on the market, how well equipment fulfills its performance specification claims and by the economics of his system. The problems of demodulation, modulation and channel conversion have been treated above. It is at this point that color degradation, "birdies", hum, and system noise can be introduced. Exact channel tuning and level control are vital. Installation factors, also, influence system quality. Shielding, filtering, wire routing and passive equipment use and location contribute to headend performance.

2. Distribution. The distribution system represents a fight between "noise" and "cross-modulation". These factors are most directly influenced by equipment selection and plant layout design. The losses in the cable, the number and location of the signals in the frequency spectrum, the distance between amplifiers, the noise factor and linearity of the amplifier, the gain, slope, and output levels required and the number of amplit ers in cascade affect distribution performance.

Noise is a random, broadband signal generated in nature by the random motion of electrons. It contains no intelligence. Noise interferes with coherent video signals in the form of "snow" on the picture tube screen, dancing black and white spots having no recognizable or repetitive shape or period, covering the entire screen. It is equivalent to "grain" in photographic film or "crackling" in radio. The "TASO" report /1 did an excellent statistical, subjective study of video noise. Their picture rating conclusion /2 indicated that "snow" was just perceptible when it was a little less than 2% (35dB) of the desired signal level and that it became somewhat objectionable at 5 1/2% (25 dB). This figure in dB is known as the Signal-to-Noise ratio.

Noise is generated even in passive resistors in an amount related to the ambient temperature. Amplifiers generate some internal noise in addition to amplifying the noise at their input terminals. This is called the "Noise Figures" of the amplifier. Each amplifier adds noise. In general, the system noise figure increases 3dB (the noise power doubles) each time the number of amplifiers in the system is doubled.

The companion distortion to noise is a problem characteristic of CATV systems that carry more than one channel in an amplifier. It cannot be blamed on the broadcaster or the program sources. It is cable's own baby. Unfortunately, amplifiers are not perfectly linear -- the output signal is not an exact duplicate of the input signal (multiplied by the gain). With non-linear circuits there is an oppo runity for interaction between the signals being carried by the amplifier to produce new unwanted signals of a distinctive nature which are the product of this interaction.

There are two types of such unwanted modulation. There are "beats" known as "intermodulation" which produce a "herringbone" effect of horizontal bars or vertical grids

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/1 The Report of the Television Allocations Study Organization to the FCC, published March 16, 1959.

/2 Corrected for a 4MHz bandwidth.

showing a regular pattern. There are "windshield wiper" or "cross-modulation" effects where the video on one channel wildly dances across the picture on another channel, sometimes so fast there is only a flicker, sometimes with picture content recognizable -- possibly as a "negative."

Although all signals in a non-linear amplifier will interact, the visual carriers - being the strongest fixed frequency signals - produce the first noticeable effects. Thus, the number of visual carriers being amplified - i.e., the number of channels being carried in a broadband system - is a determining factor in this distortion magnitude. Similarly, crossmod increases directly with the number of amplifiers in cascade. Since non-linearity usually increases as amplifier gain is increased, the factor of how hard an amplifier is driven also contributes to this interaction distortion. Conversely, the increase in crossmod due to more channels, or to more amplifiers, can be compensated by reducing amplifier gain of each amplifier. For example, generally, the system cross-modulation can be held at the same level if the output of each amplifier is reduced 3dB each time the number of cascaded amplifiers is doubled. The output reduction for adding more channels is not so simple since the total cross mod of many channels is dependent on the phasing of the various synchronizing pulses. The worst case would be if all pulses occurred at the same time. If amplifier output is reduced and the cable loss remains the same, the spacing between amplifiers must be decreased, a more practical solution than replacing the cable with one having less loss (i.e., larger diameter).

New amplifier designs are anticipating the problem of more channels by attempting to design more linear circuits and by using balanced or "push-pull" amplifier stages which cancel out some distortion products. Other partial solutions include single octave amplifiers (for example, 120 MHz to 240 MHz) The problem is recognized and the industry is anxiously waiting some breakthrough, some new method or idea that will help reduce the magnitude of the distortion problems.

3. Test Equipment. Test equipment for the measurement of system performance is becoming more sophisticated, expensive and requires more skill of operation. It used to be that a tunable, frequency selective vacuum tube voltmeter -- for years miscalled a Field Strength Meter (FSM) and now called Signal Level Meter (SLM) -- was about the only instrument available or understood. Now spectrum analyzers, which display on x-y coordinates a segment of spectrum and the amplitude of signal at each frequency; sweep generators; marker generators; high performance and wide-band oscilloscopes with electronic circuit switches or dual trace displays are much more common. Some operators have Time Domain Reflectrometers which send pulses along cable and sense any reflections, measuring the time for return and consequently the location of a fault. All of the studio test equipment of a broadcaster -- test signal generators such as multi-burst, stairsteps, windows, color bars, 20T pulses, sine square pulses and the like -- with Vertical Interval gates to insert these signals unobtrusively while a program is in progress, is now being acquired by some Multiple System Operators, and may be needed by all cable originators. Color testing requires the Vectorscope which identifies the phase and magnitude of color carrier signals.

Some items, like cross-mod test sets and differential gain/differential phase testers, just haven't yet reached a practical design or the pocketbook status of even well financed cable operators. Operators involved in microwave have still another set of test equipment requirements. It is quite likely that testing laboratories or mobile test services will evolve. A full complement of test equipment with operating crew will be rented or shared by several cable system operators. Perhaps one such laboratory will serve a whole region or area. The fact is obvious that as the cable industry grows in services and magnitude the overhead of test equipment and personnel will skyrocket far beyond the early days of the FSM and the multi-meter.

D. Standards

Contrary to the opinion of many, even those prominent in the business, there has been active and serious thought given to new cable terms, methods of measurements and to standards. The fact that so little demonstrable result can be shown is due more to the inherently slow and painful way in which professionals make progress in controversial and strange technical areas. It is not lack of desire, intent or effort.

The NCTA has had a Standards Committee and an Engineering Sub-Committee that has made progress. It has so far confined itself to terms, definitions, and methods of measurements, rather than values, or subjective qualities. Its most notable efforts have been in adoption of a standardized way of measuring amplifier distortion (primarily cross-modulation) and a method of measurement of noise. Standards have also been released on subscriber signal levels and on graphic symbols. Work is underway, together with the National Bureau of Standards, on a Primary and Secondary standard for a 75-ohm termination. The vast field of cable standards -- is being attacked and several attempts, so far unsuccessful, have been made to establish performance criteria.

The Federal Communications Commission has taken the bit in its teeth and issued (along with a quantity of proposed rules) Docket 18894 suggesting an Amendment of Subpart K of Part 74 of the Rules and Regulations with respect to Technical Standards for CATV. Comments have been invited by October 7, 1970, and it appears that shortly thereafter some or all of these proposals will be incorporated in the rules.

The major considerations in this document are:

1. Technical Standards.

2. Possible Requirement of Minimum Channel Capacity.

3. Possible Requirement of 2-Way Capability.

4. Possible Requirement of Separate Origination Centers.

5. Performance Tests and Certification.

In general, these proposed standards are reasonable and are intended to identify proper cable system performance. In some instances, the proposal is arbitrary, ambiguous and occasionally unduly burdensome. The industry and other interested parties are studying the document now and hopefully will submit comments which will remove or ease some of these points.

While the intent here is good -- the imposition of strict standards, and the obligation for proof of performance by an annual report to be filed with the Commission is an economic burden and a restriction which has not been imposed on other services under FCC jurisdiction. Broadcasters and telephone companies would be sorely opposed to similar regulations on their industry. There is no doubt but what there must be some measure of performance other than the economic control of satisfied or unsatisfied customers, but each measure should be tried and tested for worth and need after service has been stabilized rather than the imposition of packaged requirements and obligations. Certainly, performance requirements are far more reasonable for a 100,000 subscriber urban system than a 1200 customer rural operation where the cable signals, although poor, are substantially better than normal home rooftop reception.

Other professional societies, government agencies, foundations, educators, individual authors and think tank corporations have been increasingly interested in cable communication. The Wired Communications Committee of the Communications Technology Group, Institute of Electrical and Electronic Engineers, has an IEEE Cable Television Task Force. This group is made up of professional members of the telephone, broadcast, and the cable industry, consultants and government agency representatives. A sub-group of that Task Force has met with the U. S. Department of Commerce to consider voluntary standards for new cable channels. The Society of Motion Picture and Television Engineers has recognized cable and has invited representatives to be members of working Television Committees. In October 1970 the SMPTE plans a Cable Symposium as a full day session at their Annual Convention in New York. The Electronic Industry Association created a CATV Task Force which has submitted a mammoth report to the FCC covering their views on technical, regulatory, economic and sociological aspects of the industry. Other groups and committees are expending effort on an analysis of cable. The important point here is that the industry and the technology has increasing professional status and is being guided along this path at a speed and to a degree that continues to astound the industry pioneers.

SECTION

IV

NEW SYSTEM PLANNING

Section III of this report, above, was primarily devoted to existing cable systems, current terminology and practical system problems. This section will describe the current design and operational trend that will affect the thinking of a substantial portion of the industry in the next 12 to 15 months.

Without a doubt important decisions will be made on extra channel carriage. These are the how, where and why questions facing the industry. Origination facilities expansion plays an important part in this future. Two-Way transmission is making progress and equipment is now available on the market. The microwave Local Distribution Service, recently authorized by the FCC, will be in use within the next year and offers an opportunity of rapidly expanding areas of service within a 20-mile radius of existing cable systems.

A. Channel Expansion

More than 12 channel service is the major concern of many operators in the industry. Many present franchises have been obtained on the basis of offering a community additional channel selection and the local franchising authorities will expect performance on these promises in the near future. The manufacturers have had two years to prepare methods and design equipments. Some operators have been testing their existing installations for mid band use, others have installed multiple cables. Trenton, New Jersey, without one TV Broadcast station of its own (a UHF station is about to go on the air) has 17 signals from nearby cities that can be received by properly pointing a rooftop antenna. Add to this the origination, live and automatic channels, and a total of 20 channels will be required for Trenton almost immediately. But the industry still debates as to how multiple channel service should be provided. The following methods are now being tested:

1. Single Cable/Converter. The converter was discussed in some detail above in the paragraph on Home Terminal Equipment. Prominent among the reasons for using a converter is its ability to permit selection of a channel that was not allocated for standard TV broadcast and "convert" it to a channel that can be used by a normal commercial receiver. This means that with comparatively little modification of an existing 12 channel cable system, new channels could be added in the mid-band (see Table I). A converter, which may be needed for a 12-channel system in any event in areas where there are strong local broadcasting transmitters, can be expanded to accommodate additional channels for subscriber viewing. If a converter for the 12 channel system were not required, an equipment cost of $30. to $40. per customer may be involved. If a converter is already needed, the additional cost for 10 or more extra channels might be as little as $5. or $10. The unknown is how many of these extra channels can be carried on existing systems without substantial equipment replacement costs. If new amplifiers are installed, having expanded bandwidths, and better cross modulation performance, they may require different cable spacing than the 12-channel amplifier. There is a serious question as to whether all contiguous channels can be used, in the midband and the superband or whether there be gaps due to unfavorable beat or harmonic combinations.

There may be other unexpected problems. We have the equipment to get some of these answers. A cautious approach and careful analysis for the cure of problems as they arise is underway.

2. Multiple Cable. A solution to more channel capacity is, of course, available within the presently used technology and equipment availability. That solution is multiple cables. Some dual cable systems are now in operation.

As a simplified example, an existing 12-channel system could be enlarged to a 24-channel system by installing a completely duplicate plant which carries the same 12 channels but with different program material. The only requirement in addition to present equipment would be an effective cable selector switch at the subscribers set so that he could choose channels on cable A or cable B. Additional care would have to be taken at all other points of the plant, especially at the headend, to insure that none of the cable A signals entered cable B and vice versa. By extension, there could be a cable C, D, and so on.

But all is not as simple as the above description sounds. There is still the off-air (ambient) signal interference which, in a city like New York, would limit each cable to six channels without a converter (there are seven strong VHF broadcast stations in the immediate area). Thus, two cables would only provide 12 channels and 3 cables only 18. If a converter is provided so that 12 channels can be used on one cable, that same converter could, at low cost be extended to accommodate more than twelve channels -- without the need of a complete duplicate plant. Double plants do not necessarily mean double costs. Savings on installation costs could be realized if a multiple cable plant was installed originally -- but to retrofit an existing plant with multiple cables is a more costly and difficult task. One other point, multiple cable drop lines must be run into each building and to each television receiver switch. Operators are wary enough as it is of the problems of running a single cable through the house. A bundle of cables along the baseboard, around the doorways, or under the rug, causes considerable concern.

Certainly multiple cable plants will be installed. Multiple cables offer attractive advantages for two-way transmissions. Second or third cables carrying private or limited access information (such as a police or municipal or public school channel) rather than full subscriber access, seems reasonable, and the volume of traffic may demand this type of system expansion. Multiple cable plus converters brings cable capacity up to some of the "blue sky" numbers that have been suggested.

3. UHF Distribution. It is logical to ask why a cable system does not extend its frequency range up through the UHF range of the spectrum (400 to 800 MHz) and take advantage of the UHF tuners that are now required by FCC regulation for all home receivers. The contemplated FCC requirement for discreet channel selection at UHF, rather than the continuously variable tuner now used in sets, makes this even more attractive.

The reasons why this has not been used are primarily:

1) Because of the greater attenuation incurred in the coaxial cable. This increase is approximately equal to the square root of the frequency difference -- thus the cable losses would be a little less than double.

2) Solid state (transistor) devices which work at these frequencies are not as available, field tested or reliable and do not have the same performance ratings as those now readily available for the VHF range. New integrated circuits may offer new hope here.

3) There is not sufficiently large or varied enough supply of passive devices sufficiently broadband to accommodate both the UHF and the VHF frequencies.

4) The UHF tuners usually provided in commercial television receivers do not have the performance of the VHF tuners. It is generally conceded that without better tuners adjacent channel operation at UHF would not be possible. It is also questioned if the wider front end bandpass would cause cross-mod in the tuner.

5) There is continuing pressure on the FCC to reconsider UHF channel allocation — assigning it to other services which may have a more critical need for radio communication. TV sets without UHF tuners would require cable system provided converters.

4. UHF block conversion. At least one manufacturer has proposed, with equipment to support his suggestion, that channels be distributed at VHF frequencies and then block converted at the subscriber's receivers to UHF, allowing the set UHF tuner to select the desired channel. This would eliminate the need for a tunable converter but, because of the problems of commercial set UHF tuners mentioned above, adjacent channel operation is unlikely and the available VHF channel capacity would be cut in half.

5. Dedicated Drops (Discade). One British and one U. S. company are convinced that a dedicated drop system is the answer to multiple channels. Each system requires that each subscriber terminal be connected to a switching center located nearby. All programs would have the same carrier frequency. A single channel converter at each subscriber terminal would provide usable signal for a standard TV set. Channel selection would be by a telephone dial or push button arrangement working back through the drop cable to the local switching center. Thus, only the channel dialed would be connected at that switching center to a particular drop cable. The British system uses a mechanical switcher and a multiple balanced pair cable. The U. S. system uses a solid state switcher and coaxial cable. The problem of gettin- multiple programs on the same channel frequency to each local switching center would require a separate cable for each channel from the headend.

Both companies are so sure of the benefits of this system, especially for future service expansion, that they have at their own expense installed pilot systems (one on Cape Cod and one in California) for test. Cable operators have so far observed with interest but have reserved acclaim. The opportunities for system control and expansion are attractive, the simplicity of a single low frequency distribution system could greatly ease line amplifier and component problems. But the complication of line switchers and separate cables for each subscriber terminal (not one cable for each building) is frightening. Even if each local switcher station served only a few hundred terminals, the bulk of the cable and the pole line or underground installation problems gives pause.

B. Channel Reuse

More recently, with the growing demand (as in the recent FCC Docket 18894 and in the New York City negotiated franchise for Manhattan) for separate origination centers serving smaller and smaller neighborhoods, consideration has been given to channel reuse.

Trunk line routing can be planned so that there is a common point of trunk/sub-trunk feed for each neighborhood. If such a point is established a truly local program origination could be inserted at that point to serve that neighborhood. The trouble is all other neighborhoods served from that trunk would receive that same program and their own neighborhood service would have to be time shared or modulated on a different channel. Soon, the full cable capacity would be occupied with neighborhood originations at the end of the line while near the headend there would be many blank channels.

If a program on a single channel could be "erased" (totally deleted) from the trunk when that trunk crossed the arbitrary boundary into a new neighborhood, then that channel could be reused. A new local program could be inserted on that same channel for the local viewers, and at the next boundary the process would be repeated.

Deletion of a channel without degradation of adjacent channels is a difficult operation but there is some hope that it can be done. Design work is being conducted now and preliminary results are encouraging. It is quite likely that a workable system of channel reuse will be available within the time frame considered in this section.

As an appropriate aside at this point, it is increasingly apparent that many demands for channel availability have not considered time sharing. It is generally supposed that use of a channel means dedication of a channel for that particular use. Consequently, the demand for channels has occasionally reached astronomical figures. Each school and each police station does not require a separated dedicated channel. Lawyers, doctors, and other professions might share a channel. Time sharing has long been the practice of broadcasters who divide up their working day into segments as small as 10 seconds to accommodate a particular interest. Time sharing, in even smaller segments, is customary in the computer field.

Similarly, it is little understood that repetitive transmissions are wasteful of our communication resources. Unless there is new information to be added or unl... an error check is required, only one transmission is needed. Do not send the same picture 30 times a second for several minutes. Send it once, capture it on special terminal equipment for local reproduction and viewing. Release the remaining 1799 frame transmission opportunities in that same minute, to serve someone else. Time sharing of a broadband cable facility is a fantastic multiplier of services.

C. Two-Way

Historically, CATV systems have been one-way transmissions. But the cable doesn't care, it's bi-directional. Only the amplifiers, and some of the passive devices, are single ended. If proper equipment is used, information can be sent on the cable from any point on the network, back to the headend. This "upstream" transmission is in the opposite direction from the "downstream" flow of conventional cable distribution.

Obviously, a second cable could carry upstream information but a single cable can carry information simultaneously with the downstream flow if the two transmissions are at different frequencies. The amplifiers must be capable of rejecting (or be protected from receiving) those frequencies not intended for their proper direction. If this protection were not provided, the amplifier output would feed back to its own input and the circuits would break into uncontrolled oscillation. Some manufacturers are suggesting that a second cable be used for that part of the network which involves amplifiers and that upstream transmissions on a single cable be made through passive devices only.

When amplifiers are involved a gate or one-way valve is needed to keep the two directions of transmission separate. Electronically, this is done with cross-over filters. A cross-over filter accepts all frequencies at its input. It has two outputs and directs one group of frequencies to output one and another group to output two. Any frequency that is not in the downstream band could be used for upstream transmissions, provided a suitable separation filter could be built. Since expanding cable services contemplate using the "mid band" and "super band" for downstream channels, the obvious space remaining for upstream is that portion of the spectrum below channel 2 (below 54 MHz).

Now, the question is, how much information must travel upstream. If it is narrow band, for example as the FCC suggests, "at least the capacity equivalent to a single 4 KHz message channel" the problem is considerably eased. This bandwidth would allow one voice communication, or perhaps narrow band telemetry; but it would not be much harder to provide a full 6 MHz upstream band which would, for example, permit a television program to be inserted anywhere in the system and sent back to the headend. There it could be used, or recorded, or converted to a downstream channel and immediately distributed to all subscribers. Such a channel does not exclude voice channels or telemetering channels on a time shared basis but it adds the wonderful capability of remote originations anywhere within the cable area and permitting instant distribution of that origination throughout the full network.

As an impractical maximum, the full 54 MHz, or 9 TV channels, could be used below downstream channel 2. As a practical matter, the upstream transmission must be separated from the downstream band by twenty or thirty megacycles to permit a reasonable cost of cross-over filter having suitable phase and amplitude characteristics. Similarly, to simplify upstream amplifier and equalization problems, the low end of this upstream spectrum should be held in the 5 to 10 MHz range. Assume that an upstream band from 6 to 30 MHz is provided, this allows 24 MHz or the equivalent of 4 upstream TV channels, with equipment that may be costly to build and install, but well within the state-of-the-art. Several manufacturers displayed such equipment at the last NCTA annual convention and now offer it for sale. Many more manufacturers talked about it and apparently are diligently working on their own designs. A few operators are installing such equipment for cautious tests. They must find out what passive components have to be replaced, what ambient or system interferences will be encountered, what the upstream transmission does to the downstream signals, what installation (retrofit) problems will arise -- while they maintain normal service for their customers. One problem, not yet tested, is the additive effect of upstream amplifier noise from parallel feeders. This effect is not present in the downstream direction.

Some manufacturers are incorporating the two-way crossover filters and amplifiers in one package with new, extended band downstream amplifier -- as permanent circuits or as plug-in modules. This is fine for new systems but many operators will want to salvage as much of their existing downstream plant as possible. Thus, an add-on package of amplifier and filters seems desirable. Note that the cable losses are lower at the sub-band frequencies. Upstream amplifiers need be added only at every other downstream station but a pair of cross-over filters will be required at every downstream amplifier.

D. Local Distribution Service (LDS)

One of the problems of cable distribution is that it serves contiguous communities or dwellings within the limits of amplifier cascades, but will not extend its services any great distance across unoccupied land to serve smaller communities or population clusters around a cable service area. If there are not sufficient subscribers to warrant a separate headend or the cost of maintaining long trunkline spurs, those smaller clusters will not be served. Also, there are often physical or man-made barriers, impossible right of way clearances, or weather conditions which make service impractical. In large cities the high cost and public inconvenience of underground construction is a serious deterrent to cable extensions. In 1965 one MSO and a prominent electronics manufacturer requested an experimental license to experiment with a new means of using microwave frequencies to distribute multiple processed signals through the air from a cable headend (or some point on the cable plant) to sub distribution centers within a local area of some 10 to 20 miles radius. Tests were made in the 18 GHz band, which had been assigned by international agreement to commercial use but had not yet been allocated or licensed by the FCC. The design utilized a modulation method which translated a television channel at VHF to the microwave frequency without an increase in total spectrum space. Thus, a 6 MHz VHF channel still required only 6 MHz of spectrum when translated to 18 GHz. Normal FM microwave equipments use 25 MHz of microwave spectrum for a 6 MHz TV channel. In this manner, the relative spectral relationship of all the channels on the cable could be maintained. A relatively simple receiver is used to return all of the cable channels back to their original VHF processed frequencies (without requiring base band demodulation). Final distribution from that receiver point to to the subscriber's terminal in the local area was made in the conventional cable manner. Thus, a "cableless cable facility" was created which replaced trunk line without requiring physical cable plant installation or maintenance. The solid state receivers were small, about large notebook size and, with their 4 ft. (typical) parabolic antenna, operated unattended.

Tests of the equipment design and 18 GHz propagation (lack of use of these frequencies meant very little practical knowledge on characteristics) were successful. A petition for permanent allocation of a portion of the 18 GHz spectrum for this service was denied pending a World Radio Conference now scheduled to start in mid 1971. A subsequent request to permit this new service in a 12 GHz band already assigned to CATV service was granted in November 1970. This is the so-called Community Antenna Radio Service (CARS) band (shared with broadcasters) from 12.7 to 12.95 GHz. At the same time, the Commission revoked an earlier restriction, and now permitted microwave transmission to be used for cable originated programs as well as for broadcast signals.

Design changes to accommodate the frequency switch and to incorporate operational features resulting from the experiment are being made. Production equipment is expected to be available to the industry by mid 1971. Experimental transmissions, with a waiver permitting actual use in a CATV system, are continuing in New York City in the 18 GHz band. A similar test in Farmington, New Mexico has now been shut down.

In July 1970, the Commission, at the request of another manufacturer, extended the LDS rules to permit multiplexed frequency modulation for this service as well as the Amplitude Modulation granted in the original action.

E. Integrated Circuit Technology

The electronics industry is now beginning to apply the benefits of the tremendous advances it has made in circuit technology. The various forms of integrated circuits including thin and thick film, MOSchips and other advances -- as yet unfamiliar to this writer -- are being considered for cable amplifier and other cable equipment circuits. At the last NCTA convention, one manufacturer demonstrated a 300 MHz bandwidth amplifier having normal performance levels, no larger than a postage stamp. This approach is so new -- but also so positive -- that the benefits to equipment design are hard to predict. An increasing number of equipments offered to the industry can certainly be expected to incorpor ate some portions of this new art.

SECTION

V

PROPOSED SYSTEMS

The following proposed expansion for cable services is being seriously studied. Engineering design work is underway and actual hardware is being built and tested. Some of the computer services (see SRS below) will be in commercial use in as little as 12 months. However, because of the magnitude of the projects, the uncertainty of regulatory limitations, the practical design unknowns and the normal time cycles involved it is not expected that these proposed systems will be in general use for cable services before three to four years.

SUBSCRIBER RESPONSE SERVICES (SRS):

No generally accepted or suitable name for this service expansion has been adopted. Those who have considered the potential of the services that this expansion offers are unanimous in their belief that this is the most exciting advance in communications in this decade. The speed with which it will be available for productive use will itself be amazing. The technological and social timing is perfect, and a new, aggressive and competitive home communication network is, for the first time, available for its application.

Basically, SRS is a computer controlled, broadband data transmission, interrogation-response system working in close harmony with visual and aural displays and records. It benefits from the speed, memory capacity and processing potential of third generation computers. It is served by a cable transmission system that considers a one or two megabit data rate as a loafing assignment to be tucked away in some unused corner of its normal bandpass. It occurs when circuit technology compresses twenty transistor data circuits into the size of a small button. It is offered to a generation familiar with television, pushbuttons, solid state calculators and computer education. It can be made available, quickly, to serve large portions of the public. This is a wonderland of opportunity that is quickly being populated with the thinkers, the dreamers, the cautioners, the regulators, the status-quoers and, fortunately, a few doers.

On a cable communications system, capable of handling high speed data, each subscriber terminal is assigned a digital address. This address gives that terminal and the people associated with the terminal location a distinctive identification. The computer, which has memorized this address uniquely associates the address with these people, their physical location, and possibly other pertinent data such as the sociologists and the politicians may allow. The terminal at this location is told its own address -- which consists of a series of pulses, ones and zeros they are called, in some distinctive combination. For example, a string of 14 of these pulses, which at a one megabit rate would occupy only 0.000014 seconds, could uniquely identify one of over 16,000 homes. The terminal, being on a giant party line, looks at all the addresses which the computer sends out on the system and it rejects all of the addresses except its own, the only one it recognizes. It then opens its door and says "What do you want of me?".

The computer follows up the address with an instruction, also in digital form, which the terminal accepts or interprets and forwards on to some associated and cooperative device within the home. For example, the computer could say:

"How are things? Any emergencies here?"
or
"Do you have any instructions for me?"
or
"How do you want to reply to that last question on educational channel 14?"
or
"What is the reading on your water meter?"
or
"Turn on your hard copy printer, I'm going to deliver you a message (or acknowledge your instruction)(or submit to you a bill for last month's electricity)".

Now, the terminal has a chance to talk back to the computer, confirming its address and replying:

"Everything's fine here."
or
"This house just lost electric power."
or
"My water meter reads_________"
or
"My hard copy printer is on and ready to receive your message."
or
"I would like to buy that ballpoint pen just demonstrated on Channel 8."
or
"I have a message for you to collect and take appropriate action."

These replies can also be in digital form, a string of bits which have to be decoded to be understood in the illustrative language suggested above. This information is sent back to the computer over the same cable system but on an "upstream" frequency.

The amazing thing is the speed with which this action can take place. Using the megabit rate described, ten thousand of these little machine conversations could take place in less than a second. The computer must then have the capacity to sort out the replies, discard useless or no-action information, memorize and possibly act on or forward useful replies or data. If a particular terminal requires more time to conduct its business than is available in a single reply -- such as receiving a lengthy message -- the computer may give it more time than an inactive terminal, or instruct it to use an auxiliary channel where its business won't be interrupted by the normal sequence of interrogate/response. The essential thing is that a high speed, time sharing, machine assisted and disciplined transfer of information between an individual and a central point is provided by means of a cable distribution network and suitable terminal equipment. This is quite different from the public message voice network, where dedicated low band-pass pairs and elaborate switching centers allow "anybody to anybody" connections for undisciplined voice communication geared to human reception and response.

The home terminal design objective is to keep the cost of the basic subscriber's terminal very low (in the price range of other home appliances) even though some of the associated equipment like the television set, or the hard copy printer, or the burglar alarm sensors, represent additional cost.

The subscriber response services enlarge the television "window on the world" to an avenue of commerce and information for every home. The magnitude and potential, only suggested by the sketchy description above, requires careful contemplation and consideration to be fully understood.

COMMUNICATIONS SATELLITE

The October 1970 Docket of the FCC regarding expanded uses of cable encouraged networking of cable systems. Such networking provides a new opportunity, which is not channel capacity limited, for distributing minority interest programming on a national scale. An obvious way to bring multi-channel broadband communication signals to any point in the country without an impossible cross-country construction program, is by means of a domestic communications synchronous satellite. The door was opened for the programming industry use of a dedicated satellite facility, in contrast with use of common carrier services, by the January 23rd White House recommendations on Telecommunications policy. This was reinforced by the FCC invitation Docket 16495 released in March of 1970 for the establishment of Domestic Communication Satellite facilities by Non-Government Entities.

The following excerpts from a paper, "CATV Applications and Satellite Communications" delivered in a light vein by the writer at the 1970 convention of the National Association of Broadcasters, expresses some points on the satellite question.

> "The cable industry is in by far the best position of any organization or group to cause a domestic satellite service to happen now. The satellite is ideal for national or regional interconnect -- particularly from a limited number of insertion points to a vast number of receiving points. And, CATV systems, have the local terrestrial facilities, including Local Distribution microwave and coaxial cable to deliver satellite signals right into the living rooms of a vast and rapidly increasing number of homes."
>
> "Why not Comsat? --- a Comsat bird must be all things to all people. It must be big and costly and probably will be delayed until a minimum number of users are assured. It has the same problem as one of its major stockholders, AT&T, in that it cannot contract for services at a rate which can be guaranteed so that cost obligations of the user would be known in advance. It is an alternative that would certainly be attractive -- if no more attractive alternative existed."
>
> "Does the cable industry, or some segment of the cable industry, have the necessary legal, technical and financial qualifications to accomplish such an "out of this world" project? We believe the answer is "yes."

(Regarding technical qualifications) "Here we would lean heavily -- perhaps entirely, on ------a giant in the electronics and particularly in the space communications field of technology. This giant has already established a most impressive record of working satellite successes. This record includes ATS-1 and 3; Syncom 2 and 3; Intelsat I and three versions of Intelsat II. Today, the first model of Intelsat IV is under construction."

"---a complete study in depth (has been made) of the factors and trade off design of a CATV satellite earth terminal. The nature of the study is revealed by this Table of Contents:

System Requirements
Station Configuration
Cost Analysis & System Trade Offs
Antenna Sub Systems
Receiving Sub Systems
Power
Control Monitoring and Test
System Installation
Electronic Shelter
Reliability
Alternate Configurations
Transmission and Quality Requirements
Link Analysis
G/T Ratio Comparisons
Frequency Demodulator Requirements
Sun Outages
Antenna Economics.

"Similar studies are now being completed on a multi-channel bird which, although requiring only the comparatively inexpensive Thor Delta launch vehicle, will accommodate 12 channels for full national coverage, having a design life of five to seven years."

Since this paper was written Canada has decided to use the bird and ground stations described above for their national Telsat system. On August 17th the following letter was sent to the Federal Communications Commission:

"Referring to your Docket 16495, the TelePrompTer Corpo 'on contemplates a filing probably in participation with the Hughes Aircraft Company and/or others, for a domestic satellite.

Pursuant to your letter of August 7, 1970, we anticipate this filing will be ready by October 15, 1970." (signed) Irving B. Kahn.

The above excerpts and information are presented here partly for status and information as to the nature of the satellite project and its relation to CATV, partly to indicate the seriousness of the intent to establish the service. Because of the firm Canadian commitment engineering design will proceed while the Commission is deciding the merits of the several filings that are expected. Western Union has the only application on file to date.

It is reasonable to assume that if prompt and favorable decisions are made, it would be possible to have a domestic satellite service available for national CATV programming interconnection, serving a substantial number of cable systems through ground receiver stations at or near their head end, by 1974. This is well within the framework of years of the Sloan Foundation study.

The importance of the World Radio Conference scheduled for Geneva in June 1971 should be stressed here. Present domestic satellite systems have a limited number of possible ground to satellite transmit stations (up-link) at full time permanent locations because the frequencies are shared with established terrestrial services. Severe restrictions on interference from the new service require diligent and costly surveys to locate suitable "electromagnetic holes" in our national geography. The agenda of the conference will probably include consideration of exclusive satellite frequencies for uplink transmissions. Such new spectrum allocation will substantially extend the opportunities for program origination from local communities and for data feedback to national computer processing centers.

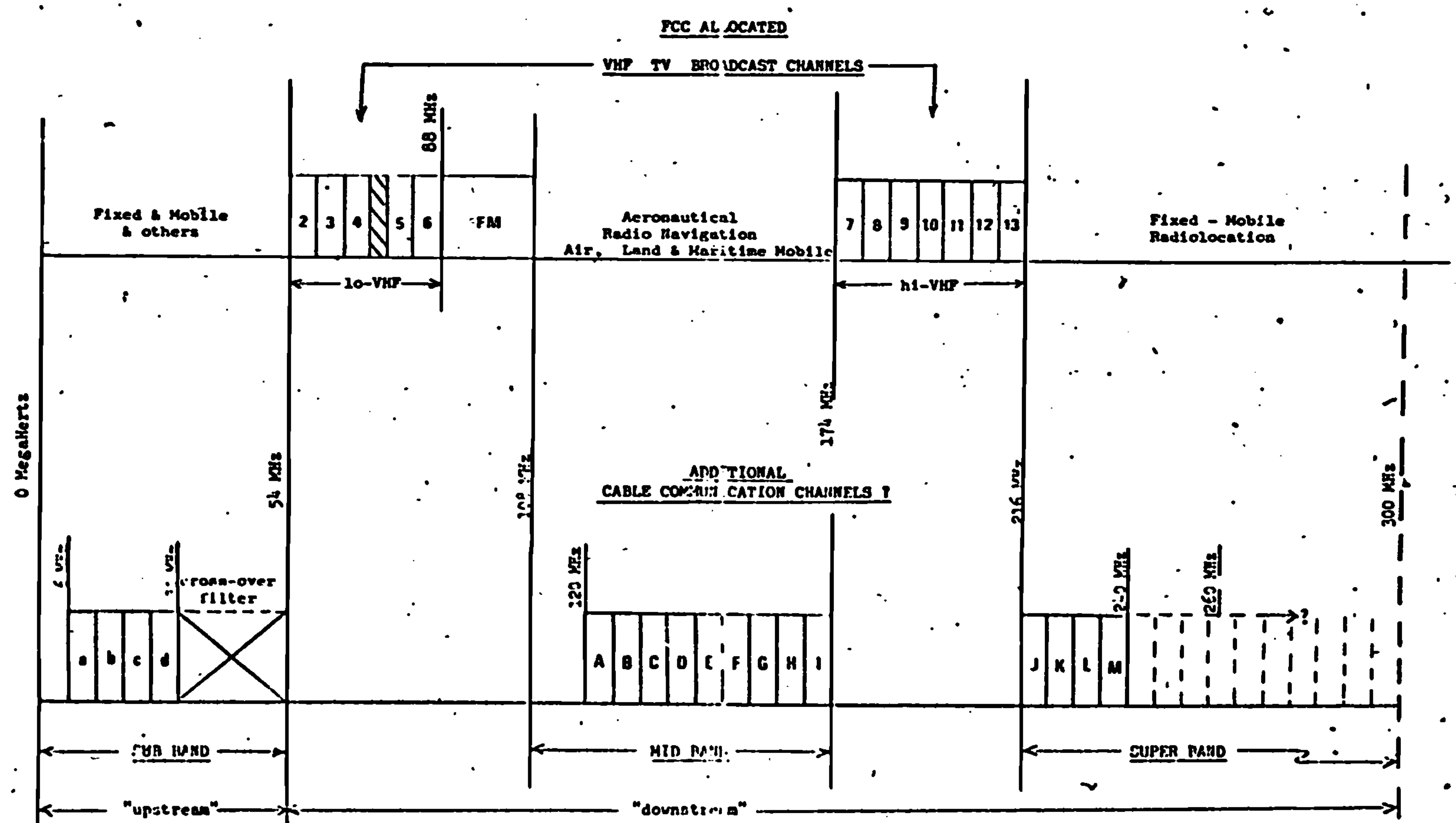
LASERS

A final "blue sky" word should mention an area of technologic development that may bear fruit within the next 10 years. Great progress is being made with coherent light beam transmission and modulation. The tremendous bandwidths available and the beam control possible in this portion of the electromagnetic spectrum make laser technology a matter for interest and careful monitoring. These advantages might permit transmission of almost unlimited numbers of TV channels without interference and without costly demodulation equipment.

SECTION
VI

CONCLUSION

Cable television, now expanding into cable communication is a healthy and vigorous business paying its own way as it goes by offering a true public service. This existing business provides the framework on which modern technology can build additional services. For various reasons indicated above the technological state-of-the-art is now, or will be within a few years span, capable of providing communication services that were never anticipated or may have been supposed to be many years off. A healthy encouragement of the development of these services would seem to be in the public interest. Certain protections, to be applied after a suitable period of experimentation and growth should be provided to prevent abusive control which might not be in the public interest. The attitude of "let's not do anything now because it may be bad" or "let's not do anything now because in a few years there may be something better" are both self defeating. The fear of intruding on the domains of established services or interests is depreciative of the ability, drive and inginuity of the men who direct those services and of the real worth of those services themselves. A wonderful communications opportunity has been created, almost by accident. Let us use it to good advantage.



FREQUENCY SPECTRUM CHART

TABLE I

ALFRED P. SLOAN FOUNDATION

Cable Commission
Technical Report
Appendix I

ARTICLE 820 — COMMUNITY ANTENNA TELEVISION AND RADIO DISTRIBUTION SYSTEMS

A. General

820-1. Scope. The provisions of this Article shall apply to coaxial cable distribution of radio frequency signals typically employed in Community Antenna Television (CATV) systems. Where the wiring system employed is other than coaxial, the provisions of Article 800—Communication Circuits shall apply.

The coaxial cable may be used to deliver low energy power to equipment directly associated with this radio frequency distribution system provided the voltage is not in excess of 60 volts and where the current supply is from a transformer or other device having energy limiting characteristics.

820-2. Material. Coaxial cable used for the radio frequency distribution system shall be suitable for the application.

B. Protection

820-3. Ground of Outer Conductive, Shield of a Coaxial Cable. Where coaxial cable is exposed to lightning or to accidental contact with lightning arrester conductors or power conductors operating at a potential exceeding 300 volts, the outer conductive shield of the coaxial cable shall be grounded at the building premises as close to the point of cable entry as practicable.

(a) Protective Devices for Coaxial Cable. Where the outer conductive shield of a coaxial cable is grounded, no other protective devices are required.

(b) Block Distribution. When coaxial cable is so located within a block containing the building or buildings to be served that it is not liable to accidental contact with light or power conductors operating at a potential exceeding 300 volts, the grounding point may be located as close to the point of block entry as practicable.

C. Installation of Cable

Coaxial cable installation for radio frequency distribution shall comply with the following:

820-4. Outside Conductors. Prior to the point of grounding, as defined in Section 820-3.

(a) On Poles. On poles, the conductors should preferably be located below the light and power conductors and shall not be attached to a cross arm which carries light or power conductors.

(b) Lead-in Clearance. Lead-in or aerial drop cables from a pole or other support including the point of initial attachment to a building or structure shall be kept away from electric light or power circuits so as to avoid the possibility of accidental contact. Where proximity to electric light and power service conductors cannot be avoided, the installation shall be such as to provide clearances of not less than 12 inches from light and power service drops.

(c) Over Roofs. Cables passing over buildings shall be at least 8 feet above any roof which is accessible for pedestrian traffic.

(d) Between Buildings. Cables extending between buildings, and also the supports or attachment fixtures shall be acceptable for the purpose, and shall have sufficient strength to withstand the loads to which they may be subjected, except that where cable does not have sufficient strength to be self-supporting, it shall be attached to a supporting messenger cable which together with the attachment fixtures or supports shall be acceptable for the purpose and shall have sufficient strength to withstand the loads to which they may be subjected.

(e) On Buildings. When attached to buildings, cables shall be securely fastened in such a manner that they shall be separated from other conductors as follows:

(1) Light and Power. The coaxial cable shall have a separation of at least 4 inches from light or power conductors not in conduit or cable, unless permanently separated from conductors of the other system by a continuous and firmly fixed non-conductor additional to the insulation on the wires.

(2) Other Communication Systems. Coaxial cable shall be installed so that there will be no unnecessary interference in the maintenance of the separate systems. In no case shall the conductors, cables, messenger strand or equipment of one system cause abrasion to the conductors, cable, messenger strand or equipment of any other system.

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(3) Lightning Conductors. Where practicable, a separation of at least 6 feet shall be maintained between any coaxial cable and lightning conductors.

820-5. Entering Buildings. Coaxial cable shall slope upward from the outside where entering a building, or, where this is impracticable, drip loops shall be formed in the cable at the point of entrance.

820-6. Conductors Inside Buildings. Beyond the point of grounding, as defined in Section 820-3, cable installation shall comply with the following:

(a) Light and Power. Coaxial cable shall be separated at least two inches from any light or power conductors or Class 1 signal or control circuits not in a raceway nor in metal sheathed, metal-clad, nonmetallic sheathed or type UF cables, unless permanently separated from the conductors of the other system by a continuous and firmly fixed nonconductor, additional to the insulation on the wire, such as porcelain tubes or flexible tubing.

(b) In Raceways and Boxes. Coaxial cable shall not be placed in any raceway, compartment, outlet box, junction box or other enclosures with conductors for light and power circuits or Class 1 signal and control circuits unless the conductors of the different systems are separated by a permanent partition; provided that this shall not apply to conductors in outlet boxes, junction boxes or similar fittings or compartments where such conductors are introduced solely for power supply to the coaxial cable system distribution equipment or for power connection to remote control equipment.

(c) In Shafts. Coaxial cable may be installed in the same shaft with conductors for light and power provided the conductors of the two systems are separated at least two inches or where the conductors of either system are encased in non combustible tubing.

Where the lighting or power conductors are run in a raceway, or in metal sheathed or metal-clad or nonmetallic sheathed or Type UF cables, neither the two-inch separation nor the non-combustible tubing is required.

(d) Vertical Runs. Conductors or coaxial cables bunched together in a vertical run in a shaft shall have a fire resistant covering capable of preventing the carrying of flame from floor to floor except where conductors are encased in non combustible tubing or are located in a fireproof shaft having fire stops at each floor.

(e) Other Conductors. There is no specific separation requirement between Class 2 Signal and Control circuits wired distribution system cables and communication cables or conductors other than the clearance necessary to prevent conflict or abrasion.

D. Underground Circuits

820-7. Underground Coaxial Cable. Underground coaxial cable entering buildings shall comply with the following:

(a) With Light and Power Conductors. Underground conductors in a duct, pedestal, handhole, or manhole containing electric light or power

conductors shall be in a section permanently separated from such conductors by means of a suitable barrier.

E. Grounding

820-8. Cable Grounding. Coaxial cable shall be grounded as follows:

(a) Ground Circuit. The coaxial cable ground shall comply with the following:

(1) Insulation. The grounding conductor shall have a rubber or other suitable kind of insulation.

(2) Material. The ground conductor shall be copper or other corrosion-resisting conductive material, stranded or solid.

(3) Size. The grounding conductor shall not be smaller than No. 18 AWG; it shall have a conductivity approximately equal to that of the outer conductor of the coaxial cable.

(4) Run. The grounding conductor shall be run in as straight a line as practicable to the grounding electrode.

(5) Physical Protection. Where necessary, the grounding conductor shall be guarded from physical damage.

(6) Electrode. The grounding conductor shall preferably be connected to a water pipe electrode. Where a water pipe is not readily available and the grounded conductor of the power service is connected to the water pipe at the building, the grounding conductor may be connected to the power service conduit, service equipment enclosures, or grounding conductor of the power service. In the absence of a water pipe, connection may be made to a continuous and extensive underground gas piping system where permitted, to an effectively grounded metallic structure, or to a ground rod or pipe driven into permanently damp earth. Steam or hot water pipes, or lightning rod conductors shall not be employed as grounding electrodes. A driven rod or pipe used for grounding power circuits shall not be used for grounding unless the driven rod or pipe is connected to the grounded conductor of a multi-grounded neutral power system. The requirements for separate made electrodes for power and lighting system grounds, those for communication systems, and those for a lightning rod installation shall not prohibit the bonding together of all such made electrodes.

(7) Electrode Connection. It is recommended that the grounding conductor shall be attached to a pipe electrode by means of a bolted clamp to which the conductor is soldered or otherwise connected in an effective manner. Where a gas pipe electrode is used, connection shall be made between the gas meter and the street main. In every case the connection to the grounding electrode shall be made as close to the earth as practicable.

820-9. Equipment Grounding. Unpowered equipment and enclosures or equipment powered by the coaxial cable are deemed to be grounded when connected to the metallic cable shield.

F. General

820-10. Prevention of Spread of Fire. Installations shall be so made that the possible spread of fire through fire walls, fire partitions or fire-resistive floors is reduced to a minimum.