THE COMPLETE TECHNICAL PAPER PROCEEDINGS

FROM:

NCTA Technical Papers

A 4.5 KM OPERATIONAL FIBER OPTIC COMMUNICATIONS SYSTEM

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Abstract

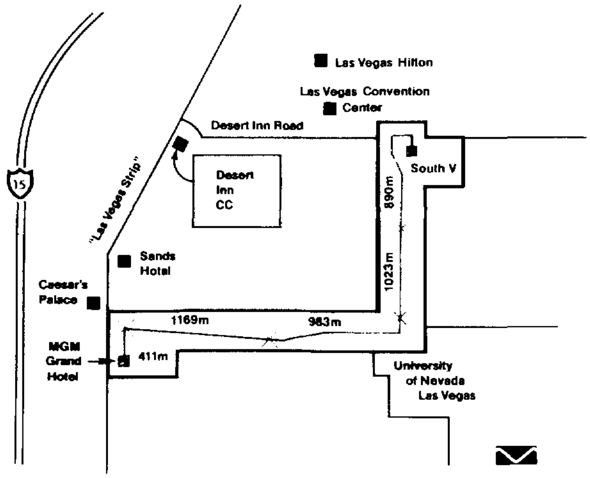
A 4.5 km (2.80 miles) operational fiber optic communications system has been installed and is currently being utilized for commercial telephone traffic. Aspects of fiber optic cable construction and manufacturing, cable placement, splicing, optical transmission equipment and field testing are presented.

Introduction

During the past several years, worldwide attention has been increasingly focused on developments in fiber optic technology and potential usage for telecommunications applications. Laboratory and development activity has advanced this technology at a rate faster than anticipated, resulting in field trial and operational systems installations.

The third such installation by an operating telephone company in the United States was recently completed by the Central Telephone and Utilities Corporation, Nevada division in Las Vegas, Nevada. The increased bandwidth and reduced repeater requirements, offered by optical communications techniques, were extremely attractive for an installation in an existing operational telecommunications system.

In December of 1977, the United States Independent Telephone Association held their annual national convention in Las Vegas and Centel, as host for the convention, decided to provide and demonstrate optical communications for the convention area in the MGM Grand Hotel. A non-repeatered T-1 PCM system was connected over a fiber optic communications link between the hotel and a central office location 4.5 km (2.80 miles) away, providing courtesy phones and a message center to serve the convention. Additionally, news services were displayed, slow scan TV was used for message posting and a remote computer was accessed for inter-active computer games over the optical link.



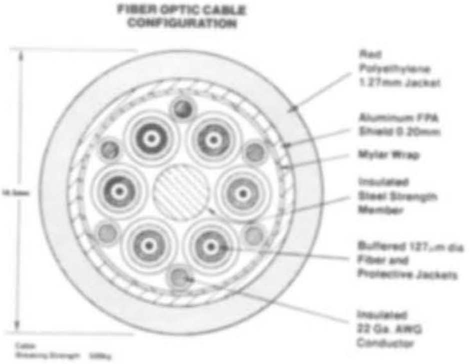
The entire system was developed and manufactured by the Valtec Corporation and its subsidiaries, Laser Diode Laboratories of Metuchen, New Jersey, and Comm/Scope Company of Catawba, North Carolina. The engineering staff, installation and splicing crews of Centel provided pre-construction make-ready, installation expertise, equipment, and personnel.

Cable Construction

Utilizing low-loss, graded index fiber manufactured by Valtec, a cable design was developed and tested which would allow direct placement in underground ducts with conventional installation techniques.

In the center of the cable is a strength member of stranded steel insulated with polyethylene. Stranded around the strength member are six fiber sub-units. Each sub-unit contains a single fiber, loosely contained in an extruded polypropylene tube. The polypropylene tubes are served with two layers of contrahelically wound Kevlar reinforcing fibers with an overall extruded polyurethane jacket to a diameter of 3.81 mm (0.150 inches). Each sub-unit was color coded for testing and installation identification. The fiber sub-unit so constructed proved to be capable of sustaining a 227 kg (500 pound) tensional force in a guage length of 50.8 cm (20 inches) around a 5.08 cm (2 inch) mandrel without breakage or damage to the glass fiber.

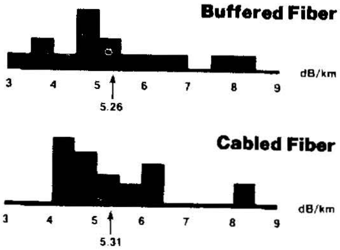
Stranded in the outer interstices of the six sub-units are six AWG 22 (0.64 mm) insulated copper wires. The entire stranded assembly is wrapped with a helically applied 0.05 mm (0.002 inch) polyester tape. A vapor barrier of 0.20 mm (0.008 inch) corrugated aluminum tape is applied longitudinally with an overlap. An ethylene acrylic acid coating on the outer surface of the aluminum tape bonds it tightly to an overall extruded outer jacket of bright red polyethylene. Overall diameter of the completed cable is 16.5 mm (0.650 inches). The cable was tested over a 100 meter (328 feet) length with a force of 500 kg (1,100 pounds) without sustaining cable damage or fiber breakage.



Factory Measurements

Spectral attenuation and pulse broadening measurements were made on each color-coded fiber sub-unit in each of the six cables manufactured. Final quality control attenuation measurements were made at seven wavelengths on the finished reeled cables. These measurements used a launch numerical aperture of 0.18 with a measurement accuracy of approximately ±0.1 dB/km. RMS pulse broadening was measured using a pulsed 900 nm injection laser diode with an input RMS pulse width of 0.30 ns. Accuracy of the RMS pulse broadening measurements has been determined to be ±0.2 ns.

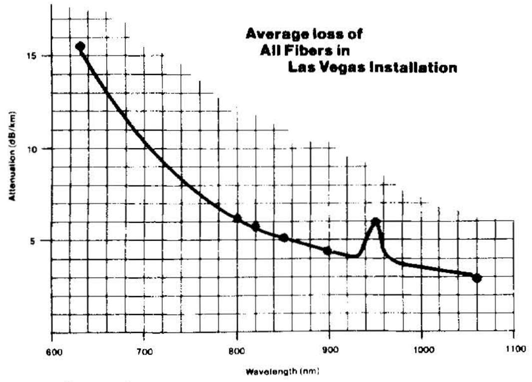
Histogram of Fiber Attenuation Measured Before and After Cabling Wavelength–850nm.



As shown, there was a slight change in average attenuation before and after cabling. A greater change was observed in distribution; possibly due to cabling losses but also contributed to by induced micro-bending loss present in buffered fiber measurements.

AVERAGE FIBER CABLE PROPERTIES

Fiber Diameter	128.9 ± 3.3 mm
Core Diameter	68.2 ± 4.0 mm
Attenuation (850 nm)	5.11 dB/km
Attenuation (900 nm)	4.62 dB/km
Numerical Aperture	0.262 ± 0.005
Pulse Broadening (rms)	2.0 ± 0.6 ns/km



Installation

The fiber cable was placed in underground ducts connecting the South 5 Central Office to the MGM Grand Hotel. Prior to the actual cable installation, Centel personnel determined duct routing, cleared ducts to be used and installed pulling ropes between manhole locations where cable-end splicing would occur.

Conventional cable handling techniques and equipment were used throughout as cable reels were positioned on pay-off trailers over manhole locations. Attachment of the pulling rope to the cable was made with a "Chinese finger" grip with swivel. A heat shrinkable boot was placed over the cable end (under the grip) to prevent water from entering the cable since ducts were far from dry. The central steel strength member was wrapped around the end of the grip and clamped back on itself so that it could take much of the pulling force. The "Chinese finger" effect distributed the remaining forces to the strengthened fiber sub-units.

The cable was paid out downward into the manhole where it was well lubricated as it entered the ducts. At the pulling end, the cable passed around a 61 cm (24 inch) diameter sheave which translated the horizontal plane of the duct to the vertical pull, exiting the manhole onto a drum driven by a winch, whose clutch was set to slip at a predetermined 227 kg (500 pound) force. Throughout the installation, pulling speeds were held to 30.48 m (100 feet) per minute.

Pulling forces were measured several times during the installation by stopping the pull a few feet before the end and inserting a dynamometer between pulling rope and cable grip. Maximum tension was measured at 136 kg (300 pounds) in the first section [890 m (2,920 feet)] installed between the central office and first splice point. In this instance, the cable route made a large 90° turn followed by a sweeping dogleg. Measured tension on the longest pull [1,169 m (3,835 feet)] was 102 kg (225 pounds).

Field Measurements and Cable Splicing

Field measurements were made on each fiber of the installed cable. An LED operating at 880 nm was used for these measurements and since the fiber was butt-coupled to the LED emitting surface, full launch aperture was approximated. Due to the uncertainty in source and detector alignment in the field, and instabilities arising from time and temperature differences between the long length and short reference length measurements, field values are accurate to approximately ±0.5 dB. Coupled optical power was measured over an installed fiber length. The detector was then brought back to the source and a second measurement was made by breaking the fiber approximately 1 meter from the source. The dB difference in the two power levels was then calculated. No increases in average attenuation were observed when compared to factory measurements.

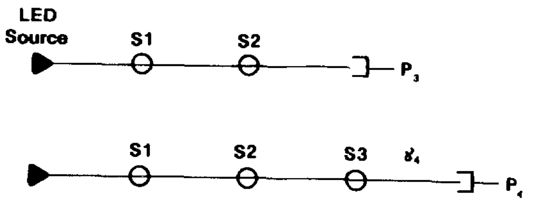
Fiber cable splicing was accomplished using a conventional telephone splice case (Smith 18" x 6 1/2") to provide a waterproof termination of the cable ends. The case was modified internally to contain a fiber splice mounting plate fixed to the center of the case. Approximately 1.5 meter lengths of fiber subunits were separated and coiled in the splice cases to provide for the possibility of future measurements and re-splicing.

Fiber splicing was done using simple splicing sleeves manufactured by Thomas and Betts of Elizabeth, New Jersey. These were tiny three alignment-rod splices with a viewing aperture in the center.

Fiber ends were prepared using a cleaving tool manufactured by Fujikura Cable of Japan to provide the clean cut, perpendicular fiber ends necessary. Prepared fiber ends to be spliced were inserted into the alignment rod splice and properly positioned by observation under a microscope. A 0.0005 to 0.001 inch gap was left between fiber ends. After the fibers were aligned, an index-matching epoxy was added through the viewing aperture. Then, heat shrinkable tubing was installed around the splice. After a brief training period, field splicing was accomplished by Centel splicing craftsmen who had no previous experience with optical fiber splicing.

Splice losses were calculated by comparing the power output from the first fiber to the splice to the output power of the far end of the fiber spliced to the first fiber. The total loss so calculated from these two power measurements represents the sum of the splice loss and the attenuation of the appended fiber. Therefore, the uncertainty in the measured splice calculations contains both the uncertainty of the field measurement and the uncertainty of the appended fiber attenuation.

Field Splice Measurement Method



$$L_{S3} = 10 \cdot \log \frac{P_3}{P_4} - \gamma_4$$

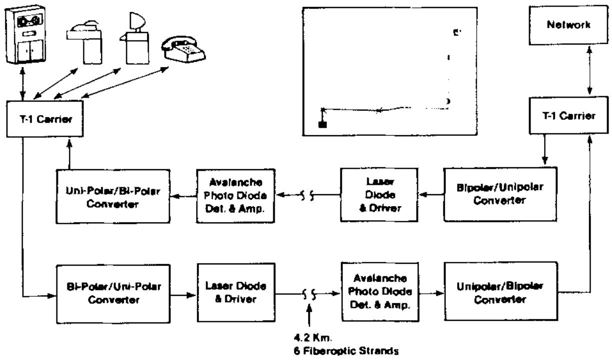
The average loss measured on 15 splices was 1.13 dB. Average cumulative loss was 0.90 dB, calculated after measuring system end-to-end loss and subtracting measured cable attenuation, giving good agreement with average measured loss and indicating approximately 1 dB as average individual splice loss.

Average end-to-end loss of the installed, spliced cable was 25.5 dB. Since the optical transmitter/receiver system was capable of accommodating approximately 48 dB end-to-end loss (for a BER of 10^{-6}), more than adequate margin was present in the system.

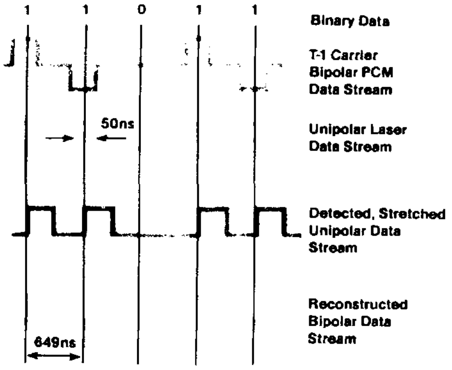
Optical Transmitter/Receiver System

The injection laser transmitter was designed and constructed by Laser Diode Laboratories of Metuchen, New Jersey, a division of Valtec Corporation. The transmitter utilizes an injection laser diode, with thermo-electric heater/cooler to maintain stud temperature at 25°C. (77°F.). A fiber pigtail is attached and protrudes from the rear of the transmitter where it is spliced to the cable fiber using the previously described fiber splicing technique. The splice is then housed in a small brass tube and attached firmly to the transmitter chassis.

The optical receiver was designed and constructed by Valtec and utilized a Texas Instruments avalanche photo detector module. Cable fiber was butted and clamped to the surface of the avalanche detector unit.



Use of an optical transmit and receive system required the conversion of bipolar PCM data at 1.544 Mb/s from the T-1 channel bank into a unipolar data stream. The normal 324 ns bipolar pulse was converted into a 50 ns unipolar pulse in order to reduce the laser duty cycle and increase its expected lifetime from 5,000 hours cw to 50,000 hours pulsed. Within the receiver, the pulses are stretched to the 324 ns width and re-converted to bipolar format, thus recreating the original bipolar data stream.



T-1 Carrier Pulse Conversions For Fiberoptic Transmission

Although a back-up optical transmit/receive system was installed concurrently with the primary system, the primary system operated flawlessly and the back-up was used only for demonstration purposes.

Conclusion

Immediately following the convention, the system was removed from the convention center and re-installed in the PBX room of the MGM Grand Hotel where it currently is in commercial usage, carrying 24 channels of voice communications to the central office. Testing has shown the optical link to be transparent by conventional T-1 PCM criteria. For the future, the fiber optic cable installation is capable of the higher PCM rates required for the DS-3 rates of 44.7 Mb/s.

A new technology has been successfully transferred from laboratory to field, and telephone company craftsmen have proven their ability to adapt to the new technology.

Acknowledgment

The authors gratefully acknowledge the contributions of Dr. Eric N. Randall, Paul J. Dobson, and Edward J. Ayers.

A CRYING NEED - TRAINING AND CONTINUING EDUCATION

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General Electric Cablevision Corporation

As our industry expands and the state of the art changes radically in so many areas we will find it extremely difficult to keep abreast of resultant technical and administration advances. Our industry is at a crossroads, we have kept up in the past but rapidly changing technology will make us as obsolete as the vacuum tube if we do not respond now. It is hoped that a sharper awareness of the need for training and further education will be recognized by the reader of this paper. The time for our industry to react in a positive manner to insure that we stay on top of technical advances and administrative expertise is now.

The theme of this convention, "Thirty Years of Innovation and Service", indicates that the cable industry has experienced many years of seasoning, however, we are still a relatively "young" industry. Our status as a young industry is further complicated by the rapidly changing technology and new innovations. The early technical changes from tube equipment to solid state now seem insignificant when we consider transitions to Local Origination to Pay TV and to Earth Stations. While the most in-depth changes have been recognized as technically oriented it has been necessary for everyone from the newest installer, to the office clerk, to the system manager to adjust to these changes.

We have remained flexible and subject to changes but we could have benefited from a strong nucleus of long time experienced people within our systems to help us weather the storm of growing pains. In many industries, such as utilities, it is not unusual to have employees with 30 and 40 years of experience who may impart their knowledge and training to new employees. The absorption of new employees may be accomplished with a minimum of disruption of normal day-to-day activities with such a nucleus of experienced long-term people. However, since most of our cable systems employ a relatively small number of people and usually do not have the backing of long-term employees, it appears that we are continually training new people.

We assign many varied responsibilities to our Service and Engineering sections. The major areas of responsibility are as follows:

* Head end and distribution installation and maintenance
* Safety and OSHA regulations
* Local Origination equipment
* Home installations
* CARS Band microwave
* Pay TV traps and scrambler and descramblers
* Earth Station installation and maintenance
* Fibre Optics (near future)
* Customer service and satisfaction
* Direct supervision and training of installers, servicemen and technicians

In the past we have relied upon vendor training, isolated seminars and courses, on the job training, and a lot of good common horse sense to keep up from both a technical and administration standpoint. Under the circumstances our industry has fared remarkably well because many good people have put forth a lot of time and effort to assure our success.

Along with the day-to-day pressures of keeping abreast technically we must also take care of the numerous installations, reconnects, disconnects, plant maintenance and customer service calls. Our training and continuing education must be sandwiched in along with many other necessary functions. While we recognize the need for more training we must also keep the store open for business. In most cases our key technical people are also key people from an administration standpoint, so it is vital that their presence be felt on a day-to-day basis in their respective system by the people reporting to them in order to keep effective communications and employee discipline intact. We must hit a happy medium between necessary training time spent away from the system and keeping their respective responsibilities intact.

While continued technical training is a high priority area, expecially in light of rapidly changing technology, there are many associated areas of concern that have become equally as important. Some of those non-technical areas of concern are as follows:

Supervision techniques - when an employee quits it may very well be the fault of a supervisor. It is a continual effort to make certain that all employees are treated fairly and equally. Employee attitudes and reliability have been proven to be lacking because of poor supervision in many cases.

Employee motivation - is one of our biggest problem areas or opportunities. Techniques for keeping interest high and competition among employees flourishing is a very challenging situation especially when we consider, once again, that with a relatively small number of employees in each system the opportunities for advancement may be somewhat limited.

Equal Employment Opportunities and new consumer credit laws - are two areas that may seem far removed from the technical area, but yet the administration of the technical area is very much concerned with these two items.

Grass roots politics - is more important every day and we just cannot get by with letting "George" do it. We must all get involved. This represents another change in the day-to-day operation of our systems which has come about in recent years. We cannot wait until we need something from our legislators to get acquainted. It is necessary to establish and maintain effective political relationships on a continuing basis.

All of the aforementioned problem areas are further compounded by the fact that a large majority of our employees are young people looking for their niche in life. Many of these people will stay with us and become very valuable employees, while others are looking only for a stepping stone in this game of life. We must accept the fact that after spending time and money to train a person to become productive, the person may then move on.

Despite all of the problems against us we continue to survive and grow and prosper. With all our shortcomings and areas of need our industry has not suffered loss of growth or prestige. Now after 30 years of innovation and service we are at a crossroad or a threshold point. All of the aforementioned areas of concern now have an accumulative effect. It's almost as if we have a tiger by the tail today--with a crying need for training and continuing education.

Training and education sources which have been at our disposal must be utilized, as in the past, to keep us alerted to technical changes and improvements. We must encourage local educational institutions to incorporate cable related courses while taking advantage of those established courses that may be of value to us, such as supervision and employee motivation. Basic safety and Red Cross instruction is readily available from local facilities. Intercompany training must be refined and expanded. Our state and national organizations may contribute heavily toward our needs.

At this point our industry must bite the bullet and move toward the sophistication of training and further education for all of our people, and certainly for the backbone of our industry--our technical people.

A RELIABLE AND REPRODUCIBLE TECHNIQUE FOR EVALUATING THE SHIELDING EFFECTIVENESS OF CATV APPARATUS

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ABSTRACT

The CATV industry has long needed a reliable and reproducible technique for evaluating the shielding effectiveness of CATV apparatus. The author will describe an operational system capable of swept frequency integrity measurements in excess of 150 dB, over a frequency range of 5-300 MHz, which technique does not require a screen room. Results of data obtained will be presented.

Long term CATV system shielding integrity has recently received substantially increased attention due to the FAA/FCC inquiry concerning CATV system radiation. Strict enforcement of the FCC radiation rules, Sub Part K, 76.605, is certain and destined to become of increasing concern for system operators.

The additional factors involving security of service on certain channels, coupled with reverse system signal requirement, all demand close attention to the selection of system components which assure long term shielding integrity.

In the face of this requirement, current experience with available rf integrity measurement methodologies [1,2,3] show substantial deficiences such as:

A) Method difficult to implement.
B) Measurements available at discrete frequencies only.
C) Measurement data influence by environmental factors not easily subject to control

The ideal measurement technology permits system component integrity measurements on an "in situ" environmental condition, and further would permit continuous integrity evaluation over a frequency spectrum of 5-300 MHz, with a continuum of measurements over the spectrum as opposed to spot frequency integrity measurements.

A major connector manufacturing firm, LRC of Horseheads, NY, commissioned the author's R & D firm to study the available technology and following on, develop measurement techniques adequate to fulfill all the desired goals.

ComSonics®, Inc. retained as co-consultants, Sachs & Freeman Associates, Inc., the eminent EMI specialists of Hyattsville, Maryland. After preliminary study it was determined that a new field detection aperature patterned after the one developed by ComSonics® for near field measurement in the Sniffer cable leakage detection system would be designed for this task.

Although the FCC radiation criteria are stated in microvolts per meter, this is a far (Fraunhofer) field intensity specification which is a function of the actual power coupled from the interior of the cable through a shield integrity fault to an external radiation element, composed of an essentially uncontrolled environment. In most cases the statistical nature of the effective aperature "A" and its directivity in this external environment preclude the precision desired for reproducible leakage measurements. Therefore, such measurements should be made in the near field, ie., $\ll 1 \lambda$, (the near field or Fresnel zone) from the radiation source to exclude those variable which are not strictly a part of the connector shielding effectiveness.

Several advantages are realized. Since this type of measurement is dependent only on the magnetic and electrostatic flux lines surrounding the sheath of the cable at the shielding flaw, the total path loss is significantly reduced, substantially improving the system's flaw detection capability. By its inherent characteristics,

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[1]- 1973 NCTA Transcripts, "A Study of Aluminum Cable Connector Interfaces and Their Effect on CATV System RF Ingress", Eric Winston.

[2]- Transfer impedance method.

[3]- Sniffer System.

a "near field" aperature is physically and electrically small[4] to a Fraunhofer (far field) aperature, significantly reducing the interference from external communications transmissions such as FM and TV broadcast facilities. The resultant data is far more reproducible and relevant to actual connector's shielding efficiency.

Far field approximations of field intensity may then be estimated from the known near field flux density.

Unfortunately, no wide band near field aperatures were available to meet this measurement requirement, therefore a major R & D program was implemented to develop such a device. Upon completion of this task, the system possessed the following capability:

* Measurement frequency range - Continuous from 5-300 MHz
* Shielding integrity sensitivity $= > 160$ dB
* Reproducibility variation $\cong \pm 2$ dB

METHODOLOGY AND MEASUREMENT SYSTEM DESCRIPTION

A block diagram of the completed measurement system is shown in Fig. 1 comprised of (a) transmission equipment and cable span distribution, (b) leakage detector probe, and (c) reception and signal processing equipment. The inside lab layout is illustrated pictorially in Fig. 2 through Fig. 4, while the outside cable spans and detector probe housing are shown in Fig. 5 through Fig. 8. A list of equipment utilized is shown in Table 1.

The system functions in a continuous sweep/reception mode covering a frequency band from 5 MHz to 300 MHz. The sweep source is provided by a tracking generator whose output frequency versus time is locked to the swept/tuned reception of the spectrum analyzer used as the received signal measurement and processing apparatus. This allows the precise simultaneous transmission and reception of a given frequency as the system continuously sweeps the entire band from 5-300 MHz. To achieve the necessary high signal level injection into the cable, the tracking generator output level is amplified to a level of 4.5 watts of power into the desired cable span under test. The high output levels utilized and high sensitivity of the receiving equipment is close proximity to the R.F. power amplifier, necessitated special isolation construction and procedures in the lab setup. By example, the 50 ohm coaxial interconnection cable from tracking generator to the R.F. power amp assembly enclosure had to be run through a section of solid copper conduit to adequately isolate this cable to avoid regenerative effects in the system. This conduit was soldered completely around the circumference of each connector, thus comprising a solid shield for interconnection. The opposite end of the pipe was inserted through an aperature in the wall of the high power transmitting enclosure and also soldered. The R.F. amplifier shielding housing was constructed of a metal enclosure large enough to house the R.F. amplifier, wideband matching transformer, additional AC power line filters, and connection cables. Two bulkhead mount feed thru type power line filters were mounted in the enclosure wall to adequately shield and filter the power lines to the R.F. power amp. An additional RFI power line filter was mounted on the inside of the enclosure to provide additional power line RFI filtering required to eliminate any externally radiated fields. Four bulkhead mounting type connectors were mounted in the enclosure shield wall to provide the outputs to the four transmitting cables feeding four cable/connector spans. The cable span being used at any time internally selected by connecting the R.F. power amp output to any one of the bulkhead connectors via a jumper cable. These construction precautions provided the necessary high degree of isolation between transmitting and receiving equipment, and precluded the necessity of special shielding techniques in the receiving apparatus apart from usual construction procedures.

As stated previously the transmitting enclosure provides four outputs to the outside cable spans interconnected by four sections of 0.5" cable which were run through the exterior wall of the testing laboratory. The cables are run underground through a section of plastic conduit, providing a protective jacketing for the cables, to one end of each of the 200' aerial cable spans. Two parallel spans were hung on cross arms with a horizontal spacing of 4' with the other two parallel spans hung 4' below the first two. (See Fig. 5) Each of the cable spans is identical in construction to the other three, consisting of a splice block interconnecting the feed cable and the 0.5" cable/connector section. Each cable section between splice blocks measures 18', with each cable span consisting of 11 such sections, interconnecting 10 splice blocks of 2 connectors each. Thus each cable span contains 20 connectors excluding the first splice block. Each

[4]- Compared to a dipole.

cable span is terminated after the 11th cable section by an appropriate 75 ohm terminator. These construction details are illustrated pictorially in Fig. 5 and Fig. 8.

Two receiving cables were mounted under the four main cable spans, each extending aerially halfway between one end of the cable spans and the center, back to the center of the span itself. At this midpoint in the cable span the two cables meet and are fed through an underground plastic conduit returning to an aperature in the exterior wall of the testing facility as was done for the four transmitting cables. These details are illustrated in the block diagram of Fig. 1 and pictorially in Fig. 8.

This construction allows detection probe access to the receiving cable point over the shortest possible distance from one end of the system to the center of the spans. Thus, signal reception is achieved via the receiving cable located under the system portion in which the measurements are being made. The two receiving cables, A and B, are run inside the testing facility in close proximity to the receiving equipment, where the appropriate interconnection is made via a short section of cable. This interconnects the chosen receiving cable/DC power inserter[5] through a wideband matching transformer converting the 75 ohm characteristic impedance of the cable system to the 50 ohm input impedance of a 20 dB low noise wideband post amp. The output of this post amplifier is then connected to the 50 ohm R.F. input to the Tektronix 7L12 spectrum analyzer, which provides the required signal processing and spectrum display. The spectrum analyzer incorporates selectable IF bandwidth, which is operated in the 300 Hz resolution mode providing the lowest system measurement noise. As the analyzer sweeps across the 5-300 MHz band, the tracking generator output is simultaneously produced, and the resulting connector leakage is monitored by the detector probes connected to the spectrum analyzer and displayed on the analyzer CRT.

A separate regulated power supply was constructed to provide +12.5 VDC and +20.0 VDC supply voltages to the detector probes and the 20 dB post amp. This supply insures fixed and reliable gain for reception calibration. The probe powering supply output is switchable allowing power to be interrupted when outside receiving cable disconnection/connection is being made.

5 - Used to feed the DC supply to the external detection probe/preamplifier.

RF LEAKAGE DETECTION PROBES AND HOUSING

Connector leakage detection is accomplished by precise physical placement of two near field flux probes located in close to the connector under test. Fig. 7 illustrates construcion of the probe housing and interconnections. Circular notches are cut in two sides to allow the housing to be hung easily on each cable/strand assembly from the ground, as illustrated in Fig. 6. Physical location of support bearing and lateral mounting of the two probes are tightly controlled to facilitate measurement of each connector within narrow limits of distance to each end of the two probe housings. With the spacing thus controlled, the housing can then be moved along each strand to assure that each connector is directly under the probe at time of measurement.

Since there are many connectors mounted on the same energized cable span, leakage from any one connector will be launched along the cable sheath, propagating to other connector locations, combining with leakage measurements being made at a particular connector. The shielding integrity of any connector can potentially degrade sufficiently over time to cause significant signal contributions at other connector test locations and thus introduce errors which result in false spectral signatures in the measurements. It was, therefore, necessary to develop a method to isolate the leakage of a particular splice block from other splice blocks in the cable span. It was determined that an antenna probe housing was needed providing at least a semi-enclosed, R.F. shielded environment for the two leakage detection probes. Fig. 6 and 7 pictorially illustrate the constructed housing. A lightweight metal frame was covered with a fine mesh metal screen, which covered the top, back and two side frame panels, and is physically connected on each side to a multi-layer RFI shielding mesh lining the circular support notches. This mesh provides an electrical contact from the housing to the cable span sheath achieving excellent reproducibility. In early measurements it was also determined that the antenna probe circuit ground must be electrically referenced to the cable sheath very close to the point of radiation. This effectively desensitized the probes to radiation other than leakage produced by the connector under test, and effectively eliminates effects of external signals induced via the receiving cable sheath. Probe referencing connection is provided by two stainless steel rods, as illustrated in Fig. 7, each connected to one probe mounting bracket in such a way as to be under tension against the cable sheath or splice block as the housing rests on the cable at the two support locations.

One antenna probe operates from 5-100 MHz and the other from 100-300 MHz. A combiner/filter module was constructed to connect the two probes to a common output cable, while maintining a high degree of electrical isolation between the individual probe outputs. The highband probe filter input allows only those signals from 100-300 MHz to pass to the common output, while the low band input passes signals only from 5-100 MHz, thus allowing completely independent operation of the two probes. DC power for the probe/preamplifier combination is supplied via the receiving cable. Both probes are small aperature/near field flux/sensing devices, arranged to perform their function in an essentially frequency independent mode. This technology allows the discrete analysis of a small radiating aperature area, such as a single connector in a splice block.

The pick-up loop output in connected to the input of a low noise MOSFET preamplifier stage. This stage provides the requisite match for the antenna sections, also achieving the low input noise floor required for high leakage detection sensitivity. A broadband transformer was constructed for impedance transformation and signal coupling the FET output to the 75 ohm cable input. This transformer also provides DC power connection from the probe output port to the preamplifier stage.

SPECTRUM PHOTOGRAPHS INTERPRETATIONS

Several leakage spectrum photographs are labeled here for comparison. Each photograph contains necessary quantitative information on the spectrum analyzer calibration/display mode settings. The alphanumeric readout on each photograph indicates the signal level vertical display, scaling at 10 dB per main horizontal graticule division, a full scale (top graticule line) reference level of -84 dBm, and a bandwidth or resolution setting of 300 Hz. The lower right hand display of <50 MHz indicates a horizontal frequency scale calibration of less than 50 MHz per division. This is due to the frequency scale calibration of 30 MHz per vertical graticule division, 0[6] Hz is on the extreme left hand vertical scale line and 300 MHz is on the extreme right hand vertical scale line, displaying the total spectrum of 0-300 MHz over the entire CRT display. Since there are 10 main vetical divisions viewing from left to right, each division of change equals 30 MHz. The exact center of the display then represents 5 divisions of 150 MHz.

As was stated, the full scale or top horizontal line indicates a received signal strength of -84 dBm or 84 dB below one milliwatt at the detector probe antenna output terminals. The lowest calibrated full scale reference of the spectrum analyzer is -60 dBm, measured at the analyzer's input port. The broadband gain of the detector probes is 4 dB, and that of the preamp immediately preceeding the analyzer is 20 dB, for a total of 24 dB broadband gain. Therefore, -60 dBm -24 dB = -84 dBm true full scale reference level as indicated in the photograph display. As stated, each vertical divsion equals a 10 dB change in signal level. The midscale graticule in the photographs then represents a -124 dBm level.

The photograph labeled "Noise Floor" represents total receiving system detected spectrum with no signal input to the cable spans and with the energized detector probe assembly hanging outside on one of the cable spans. The display then represents total receiving system noise output and detected pickup of any remote sources of radiation present at the outside measurement site. Therefore, this spectrum representation is defined as the measurement system noise floor or lowest detectable signal levels possible in the measurement system. A reduction in spectrum analyzer resolution reduces the undesired received noise power that would mask any desired signal to be displayed. The analyzer is, therefore, operated with its lowest obtainable bandwidth or resolution of 300 Hz as represented on the spectrum photographs. The system noise floor level, excluding the individual carriers present in the display, ranges from about -134 dBm out to 150 MHz, to about -140 dBm to 300 MHz. The 4.5 watt output level maintained into any of the cable spans converts to +36.5 dBm, resulting then in a total system measurement dynamic range of 36.5 + 134 = 170.5 dB minimum. Thus the receiving apparatus can display detected leakage signals at the antenna probe head output terminals (preceeding the first probe preamp) that are 170 dB reduced from the level present in the cable span, less any cable losses.

Referring to the noise floor photograph, several individual spectrum lines can be seen at levels significantly above that of the -134 dBm noise floor. These represent extraneous signals present at the measurement site, consisting in part of

6 - Lowest actual measurement frequency is 5 MHz.

VHF television band channels, FM radio broadcast signals, and other business communication signals. The two highest levels seen at 90.7 MHz and 100.7 MHz are being received from two local FM broadcast stations.

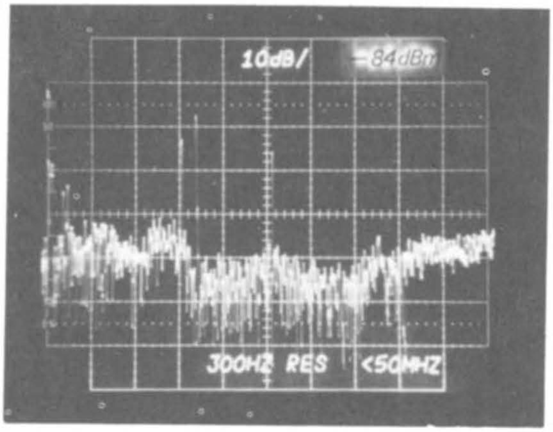
SUMMARY

Test results indicate a reproducible and reliable individual component integrity measurement system, permitting continuous evaluation over a frequency spectrum of 5-300 MHz. Utilizing near field detection methodology and isolation properties of the developed detection probes housing, it is possible to obtain individual components spectral signatures in a multi-component system, thus permitting a more meaningful and relevant analysis of a variety of system components on a statistical basis. This then allows a "typical" performance pattern definition on a particular component group, as well as relative group comparisons. Test results also indicate the capability of more accurate location of the component leakage point, thus facilitating accurate definitions of integrity failure mechanisms.

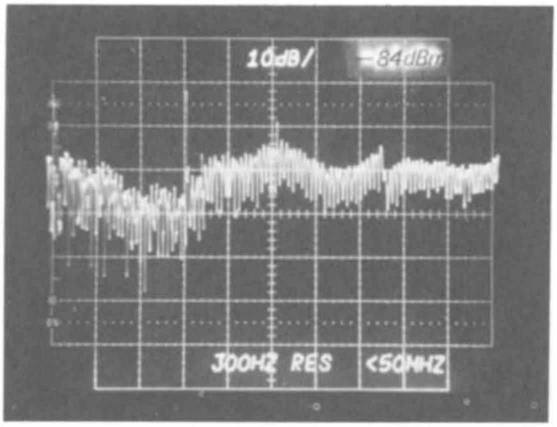
Spectrum pattern data obtained for several different connector types have shown easily detectable spectrum signatures of non-integral mandrel connectors and a variety of integral mandrel types. Cyclical pattern variations due to temperature fluctuations, frequency selective integrity degradations, and general shielding integrity deficiencies over certain selective portions of the measurement band have been identified as a result of the 5-300 MHz spectrum measurement methodology. Such results would obviously not be possible from single connector, spot frequency measurements.

This same measurement system methodology will be utilized by ComSonics®, Inc. in the near future for flexible coaxial cable connectors. However, several characteristics unique to this type of cable require further development for successful measurement implementation. Shielding effectiveness of flexible cable itself is significantly less than the measurement system sensitivity. Unless the integrity of the connector/cable interface is lower than the cable integrity, additional isolation techniques will be needed for relevant measurements. As for hardline connectors, signal levels at a particular connector can be influenced by degrading connectors at other points in the cable span. Present solutions to this problem by special detection probe housing construction will be difficult to implement due to the nonconductive outer jacket of flexible cable to be used for connector point connection. Methodology and apparatus developed for hardline connector measurements will be expanded further to provide reliable testing for this special case.

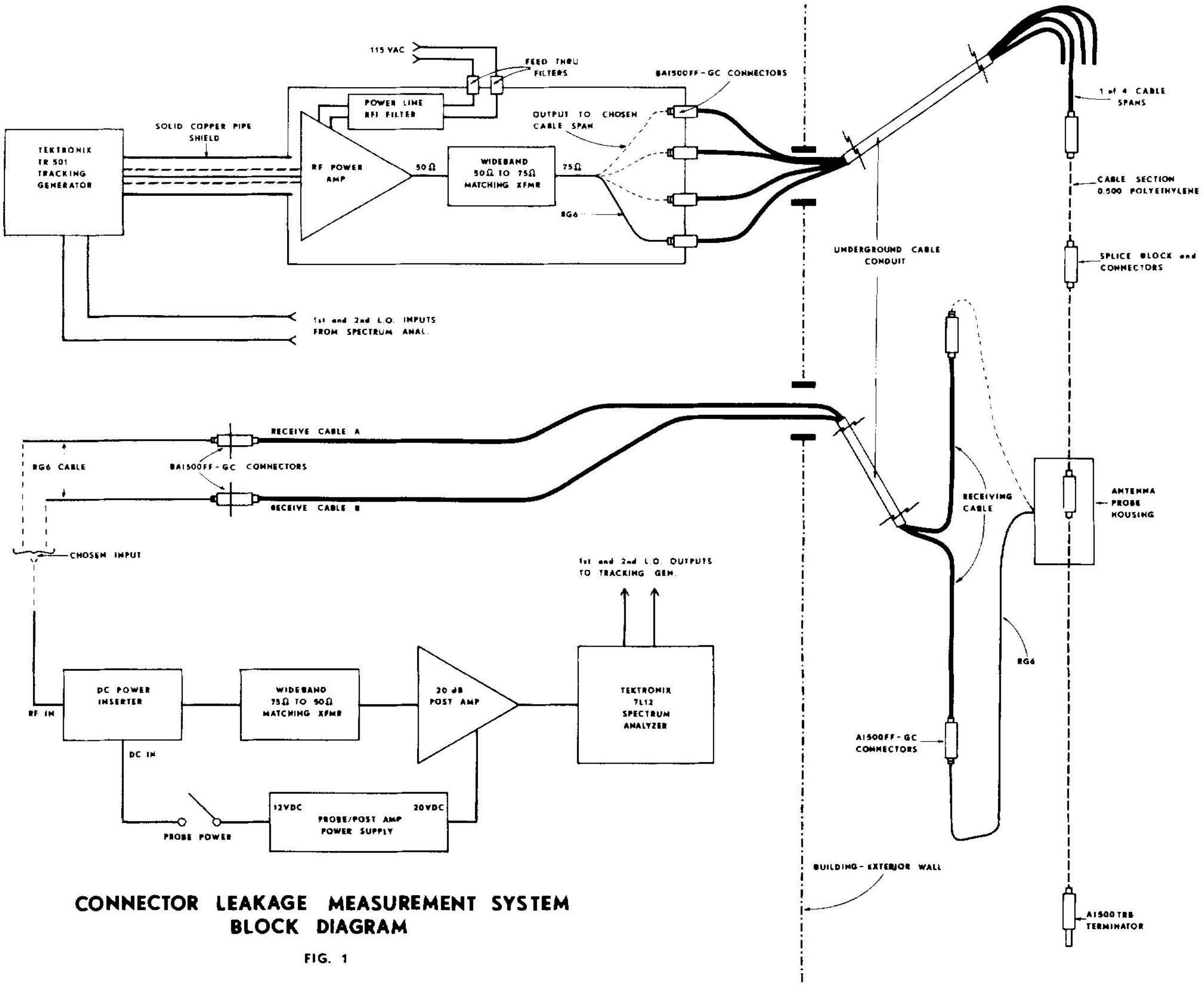
The author wishes to thank Richard Shimp, Director of Research and Development, and Glen K. Shomo, III, P.E., Assistant Director of Research and Development at ComSonics®. Both of these engineers worked diligently and brilliantly, solving some very difficult, state-of-the-art problems.



INTEGRAL MANDREL



NON-INTEGRAL MANDREL



CONNECTOR LEAKAGE MEASUREMENT SYSTEM
BLOCK DIAGRAM

FIG. 1

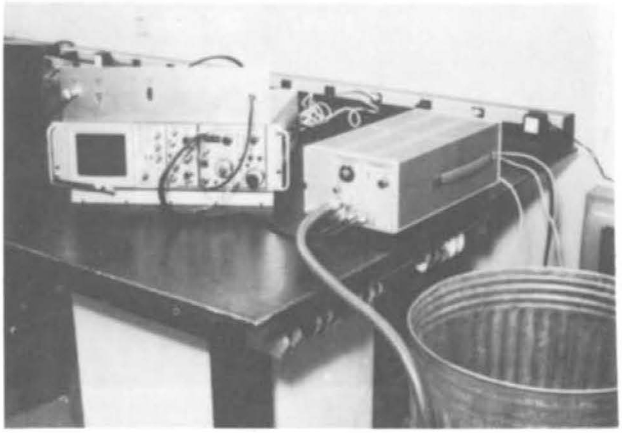


FIG. 2 - Measurement System Apparatus

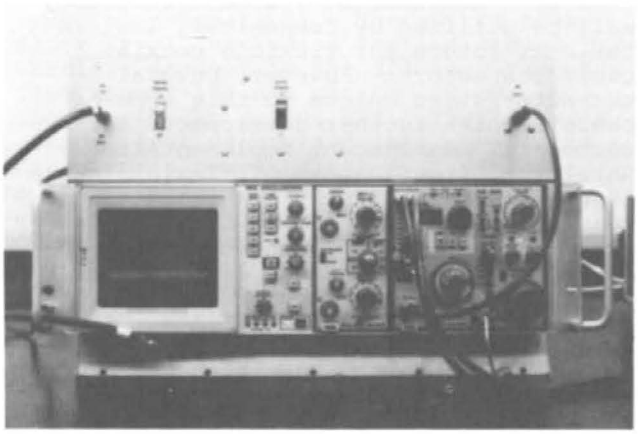


FIG. 3 - Receiving & Processing Apparatus

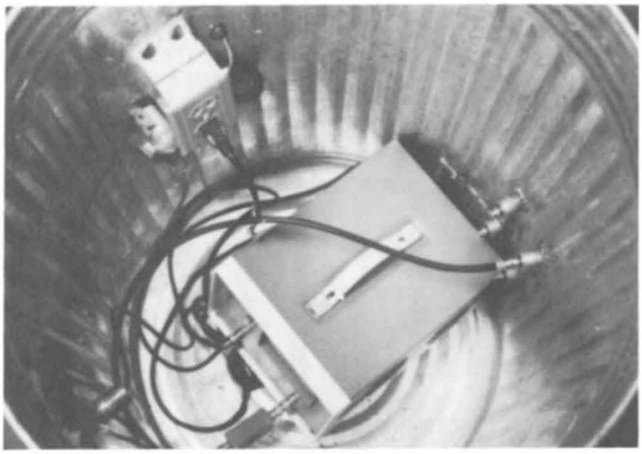


FIG. 4 - Power Amp Assembly Enclosure

FIG. 5 - Cable Spans Feed Points

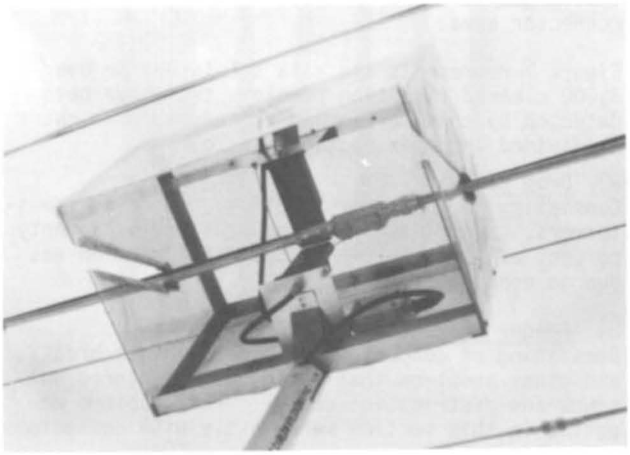


FIG. 6 - Detection Housing -
Operational Placement

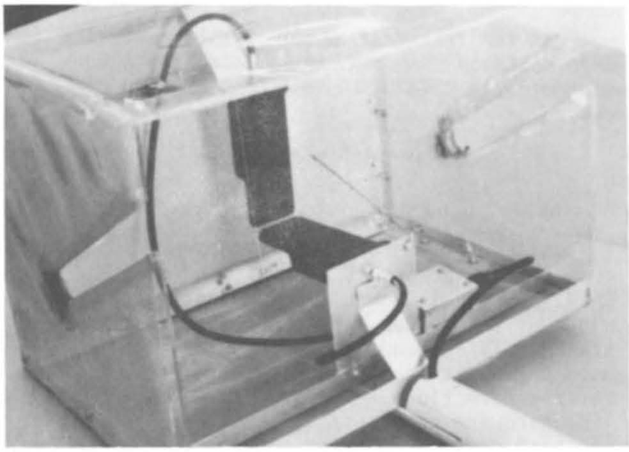


FIG. 7 - Detection Probes & Housing

FIG. 8 - Cable/Connectors Construction

A Time Compression Multiplex System For Multiple Video and Data Distribution Using Existing Satellite Channels

Donald Kirk, Jr.

Digital Communications, Inc.

Abstract - A multiplex system is described in which sequential segments of two video signals are time compressed and interleaved in analog form for transmission over a satellite transponder. Channel information rate and S/N are considered. The Time Compression Multiplex approach is extended to data plus video and two way video cases. A signal enhancement system for S/N improvement is proposed.

Introduction Starting with WESTAR I in April of 1974, four domestic satellites have been placed in geostationary orbit to serve miscellaneous customers in the continental United States. They make available a total of 72 transponder channels, each of 36 megacycles bandwidth, for transmission of various kinds of signals. A number of services including multi-channel telephone and high rate digital data transmission have developed to use these channels. At present, one of the fastest growing users of satellite channels is the CATV industry with its need for color video transmission.

Because of the high cost of satellite transponder channels it is natural that we should question the efficiency with which they are used. For multi-channel audio or data the efficiency of time bandwidth utilization controls the selection of the multiplex method chosen to assemble the various signals for transmission through a common path. A number of such multiplex systems are described in the literature.(1)

The situation for video transmission is more complex. Several systems which can transmit two video signals over one transponder channel are suggested in the literature,(2) but none of them are in widespread use. It is the purpose of this paper to propose another system called Time Compression Multiplex which may overcome some of the problems encountered by the earlier systems.

The permissible cost of a multiplex system can be examined by considering the case of an operator who is currently delivering one channel of video via one satellite transponder to N earth stations. To deliver a second channel he may lease a second transponder and provide a second receiver at each earth station. The cost per earth station C is then:

$C = R + \frac{T}{N}$, where R is the cost of a receiver and T is the present value of a transponder channel. A useful multiplex system should have a receiving terminal cost of less than C which is in the range of $\$1.7 \times 10^4$ to $\$4.4 \times 10^4$ as N varies from 300 to 100. (Assuming $R = 4 \times 10^3$ and $T = 4 \times 10^6$). If a value is assigned to spectrum conservation as well as to hardware the allowable terminal cost would be considerably larger.

Frequency division multiplex, or Frequency Division Multiple Access as it is called in Satellite circles, has been widely used for transmitting a large number of telephone signals over a single transponder channel. Figure 1 is a block diagram showing how this technique might be used to carry two video channels with one transponder. Unfortunately, when two independent signals are passed through the satellite channel the average power output must be reduced by something of the order of 6 dB to reduce the intermodulation products to acceptable values. In addition, the FM deviation must be reduced by about 8 dB because of the reduction in available bandwidth. For performance comparable to a single channel system with a 15 foot dish, a two channel system would require an antenna of over 50 ft. diameter.

Other approaches to Frequency Division Multiple Access experience the same signal to noise ratio problem. For example, let the proposal be to use two 6 MHz AM channels instead of the 18 MHz FM paths. The noise bandwidth of the receiver is now less, but there is no FM improvement, and the back-off in satellite power must be greater to prevent intermodulation problems.

The intermodulation problems of Frequency Division Multiple Access can be eliminated by going to some time division system in which the two information streams do not use the transmission path simultaneously. In order to examine the available Time Division Multiplex possibilities we need to first establish the data rates involved.

Channel Capacity Conventional sampling of a 5 MHz video channel and use of an eight bit PCM code yields a data rate of 80 Megabits/sec. or 160 Megabits for two video channels.

Application of Shannon's Theorem for a band limited channel in the presence of white noise

(1) $R = B \, \mathrm{Log}_2 \, (1 + S/N)$ bits/sec.

to a satellite down-link of bandwidth

$B = 36$ MHz

and a carrier to noise ratio

$S/N = 12$ dB

yields a limit for the information rate of

$R = 146.7$ Megabits/sec.

Clearly, two signals requiring a total data rate of 160 Mb/s cannot pass through this channel.

Let us examine the video channel more closely to see whether the conventional PCM encoding approach was efficient. We know that a useable video signal can be passed through a circuit of about 4.2 MHz bandwidth with a delivered signal to noise ratio of about 46 dB P-P/rms. Reducing this to an rms/rms value of 37 dB and using (1) again we find that the greatest data rate which the video channel can have is 51.6 Megabits/sec.

Two different approaches have been reported in the search for a more efficient method for encoding a video channel. In one approach the video signal is stored and examined at the transmitting end of the system. To the greatest extent possible, redundancy is removed from the signal, and what is left is encoded and transmitted.

In the second approach alternate frames of each video signal are deleted at the transmitting terminal and the remaining frames are time interleaved for transmission on a common path. At the receiving end the incoming data is stored and made available to a computer which is programmed to predict what the missing frames probably were.

Using the first system, good picture quality has been reported with data rates of 33 to 43 Megabits per channel. Two channel operation over a single transponder with a 15 ft. receive dish has been demonstrated. Some picture degradation is reported with the second approach. With each of these systems some costly storage and computational hardware is required.

The TCM System If the second system is modified somewhat we can avoid the necessity for omitting part of the incoming data at the transmitting terminal and predicting its probable value at the receiver. Figure 2 shows an arrangement in which alternate blocks of data from a video input, A, are stored in two stores A-1T and A-2T. The same treatment is given a second signal, B. The stores are read sequentially into a common path in the order shown. The reading speed is twice the real time writing speed used to record the data in the store. Thus, in the common path, time is apparently compressed to half its real value, and spectral components of the incoming signals are doubled in frequency.

At the receiving terminal the process is reversed. The signals are read into the stores at high speed and read out into separate lines in real time. We will call this complete process Time Compression Multiplex (TCM).

To investigate the ability of a satellite channel to carry the TCM signal, recall that the signal to noise ratio of the FM channel is related to its carrier to noise ratio by

$$(2) \quad \frac{S_{rms}}{N_{rms}} = \frac{C}{N} \left[3 \left(\frac{\Delta f}{f_m} \right)^2 \frac{B}{f_m} \right] \left[\frac{(2\pi f_m T)^2}{3} \right]$$

where Δf is the peak deviation

f_m is the highest modulating frequency

B is the I F bandwidth and

T is the de-emphasis time constant

For our example let $f_m T = 1.25$; in which case the third factor, giving the effect of use of pre and de emphasis, is 13.1 dB.

Let the deviation and the highest base band frequency be related to the bandwidth by Carson's rule.

(3) $B = 2(\Delta f + f_m)$

Using (1), (2), and (3) we can plot the information capacity of an FM channel as a function of highest modulating frequency. This has been done in Figure 3. For the single channel case where $f_m = 4.2$ MHz, we have an excess channel capacity of about 17 Megabits. For the dual channel case assuming f_m of 8.4 MHz the excess channel capacity is about zero. (In both cases we are assuming that the required data rate for the analog channel is 51.6 Mb/sec. as previously calculated.)

For $S/N \gg 1$, we may restate Shannon's Theorem, (1), as

$$R_1 = B \, Log_2 \, (S/N)_1 \quad \text{and}$$

$$R_2 = B \, Log_2 \, (S/N)_2$$

By subtraction

$$\frac{\Delta R}{B} = Log_2 \left[\frac{S/N_1}{S/N_2} \right], \text{ where } R_1 - R_2 = \Delta R.$$

Then

$$\frac{\Delta R}{B} \; 10 \, Log_{10} 2 = \Delta \, S/N \text{ in dB},$$

is the relation between excess channel capacity expressed as bit rate and available noise margin expressed as S/N in dB.

It can be seen that unless the data rate of the two channel TCM system can be somehow reduced, the system will have no noise performance margin.

The previous computation which indicated that a video channel could represent a data rate of as much as 51.6 Mb/sec. assumed that all times were equally important in the video signal. This is not necessarily true. The active portion of the video scanning line occupies only $\frac{108}{130}$ ths of the total time. The remaining $\frac{22}{130}$ ths of the time is used for horizontal synchronizing signal which has very low information content. If we can save most of this time we can reduce the data stream by

$$2 \times 51.6 \times \frac{22}{130} = 17.5 \text{ Megabits/sec.}$$

Using this reduction in data rate for an 8.4 MHz channel in (4) indicates that we may be able to achieve a 6 dB improvement in Signal to Noise Ratio. All of this improvement will not be realized in the design of a system because some of the available data rate must be assigned to the audio channels and to synchronization.

Application of TCM to Two Video Channels

Before proceeding to a sample system design consider again the block diagram of the TCM system in Figure 2. The signals going into the storage units are analog in character. Those coming out into the common line are also analog but they occupy half as much time, and their spectral components are doubled in frequency. The stores are not necessarily analog. They could be digital shift registers preceeded by an A/D converter and followed by a D/A converter. Recently there have become available some Charge Coupled Devices (CCD) sometimes called "Bucket Brigade Delay Lines" which can perform the storage function without the requirement for the A/D and D/A conversions. In these devices an amount of charge proportional to the analog input voltage is shifted through the cells of the device in response to a clock signal. When this charge eventually flows through an output resistor it reproduces the analog input voltage but delayed in time. By having available two clock frequencies one may place a line of video in store at one rate and read it out of store at a different rate.

For either the digital or the analog the data is acquired by a sampling process, and the time between samples can be no greater than the Nyquist interval or $T = 1/2 \, f_m$ sec.

There is no requirement that samples of the input signal be taken all the time. During the sync interval the value of the signal is known, and no samples need to be taken. This reduces the total number of samples to be transmitted and thus reduces the maximum frequency in the common line.

There is no requirement that the two clock rates be related by a 2:1 factor. The clock which reads information out of store and into the common line is chosen to be fast enough to move the required number of samples in the available time leaving enough time to insert a small data stream containing the two sound channels, system sync, etc.

The common line of Figure 2 corresponds to the Earth Station Transmitter - Satellite Transponder - Earth Station Receiver of a satellite relay system. In this line, the highest frequency necessarily present would be

$$f_m = \frac{1}{2} \; \frac{\text{Total number of Samples from two video lines + DIGITAL}}{\text{Time of one horizontal line}}$$

The digital group representing sync and sound channels would be treated as a frequency shift keyed signal of either Binary or M'ary type.

In the common line we need to be concerned with the time of transition from one of the analog signals to the other. In general, it is limitations arising in this transition time which have restricted the usefulness of Pulse Amplitude Modulation Systems to which the TCM system may be compared. Limitations in the phase response of the common line can cause a sudden amplitude transition to be accompanied by a precursor or tail (ringing or overshoot). By this mechanism, cross talk between channels is created.

We can avoid half of the problems of this cross talk by making the transition from one analog signal to the other during the sync interval of one of the signals. At the receive end of the system, we will generate and reinsert clean sync in this channel. Thus the effects of the cross talk will be removed.

In the general case the two video signals will have no fixed relation between their sync times. Thus, while the above fix works for one master channel (to which system sync is keyed), it is of no help for the slave channel. For the slave channel the problem may be avoided by transmission of a small amount of additional information.

In Figure 2, let the samples stored in Store A-1T be taken from Channel A video starting and ending during A blanking. Then add a few samples of B video taken from the B line just preceeding the samples used to fill store B-1T from the B line (with a pause in loading during B sync time). Load a few extra samples of B video after the complete line is loaded. (These samples will be duplicates of the first few samples in B-2T).

When read into the common line there will be no channel transition at the time when loading of B-1R or B-2R starts or stops because the common line is carrying B information on both sides of these points. Let us make a trial system design based on a video channel of about 4.2 MHz bandwidth and a store which can hold 455 samples. For NTSC video all of the frequencies and intervals are related to a master frequency, F_M = 14.31818 MHz. The time building block is:

$$T_A = \frac{7}{F_M}$$

The horizontal line time is 130 T_A, and this becomes the time in which we must read out both video stores plus the digital store. In loading the store let this horizontal line time be equal to 532 sample times, (T_{SI}). Then, maximum base band frequency we can handle is

$$f_m = \frac{1}{2\ T_{SI}} = \frac{532}{2 \times 130\ T_A} = \frac{532\ F_M}{2x7x130} = 4.19\ \text{MHz}$$

The active portion of the video line is $108T_A$ long which corresponds to approximately 442 T_{SI}. A typical load for an A store would then be:

4	samples of A Blanking level
442	samples of A active video
4	samples of A Blanking video
5	samples of B video for cross talk prevention
455	Total samples

For the B stores the load would be the same except that the 8 samples of blanking would come somewhere in the middle of the store, and there would be a pause during loading in response to B sync.

When the samples are read out into the common line, let us use the following sample assignment:

455	samples from A-1T
455	samples from B-1T
32	sample times for Master sync.
10	sample times for A/B Sync difference
16	sample times for A audio PCM
16	sample times for B audio PCM
16	sample times - Spare at this time
1,000	Total sample times

The sample time into the output common line is

$$T_{SO} = \frac{130\ T_A}{1000}$$

We can now calculate the maximum base band video frequency which must be transmitted over the satellite as

$$f_m = \frac{1}{2\ T_{SO}} = \frac{1000}{2x130T_A} = \frac{1000\ F_M}{2x7x130} = 7.87\ \text{MHz}$$

One may well object to a system design which calls for sampling at the Nyquist interval. Note, however, that this is an internal problem which may be resolved by using a larger number of cells in the store. The ratio of the top frequency in the video input to the highest frequency presented to the satellite transmitter base band is:

$$\frac{f_{m\ video}}{f_{m\ B\text{-}B}} = \frac{532}{1000} = \frac{4.19\ \text{MHz}}{7.87\ \text{MHz}}$$

If a store with 910 rather than 455 cells had been used this ratio would have stayed the same. Sampling rates within the multiplex equipment would have doubled and the digital samples would have been twice as long in terms of sample times but the same length in real time.

The numbers chosen for the example come from an attempt to design around an existing CCD storage device of 455 cells which may be driven at sampling rates as high as 16 Megasamples/sec.

Let us compare the noise performance of this two channel TCM system with that of a conventional single video channel over a satellite transponder. The path of interest is the downlink and we will use a carrier to noise ratio of 12 dB for the TCM system. For the single channel system the C/N will be increased to 12.8 dB to take into account the fact that a receiver of 30 rather than 36 MHz bandwidth is often used in current practice.

A relationship which is frequently used is

$$(5)\quad \frac{S_{p\text{-}p}}{N_{rms}} = \frac{C}{N} + 20\ \text{Log}\,\Delta f + 10\ \text{Log}\ B - 30\ \text{Log}\ f_m + 10\ \text{Log}\ 6 + EW$$

Where the emphasis weighting factor is 13.1dB

For the single channel case where

Δf = 10.5 MHz peak deviation and

f_m = 4.2 MHz highest base band frequency

the result is S/N = 50.2 dB

For the two channel TCM system the applicable factors are:

f = 10.13 MHz,

f_m = 7.87 MHz,

and the result is S/N = 41.7 dB

The single channel system would normally transmit video with sync having a maximum amplitude of 160 IRE units (including maximum color signal). In the TCM system the sync signal would be regenerated and added at the receiving end. Thus, the maximum P-P value for its video would be 140 IRE units. A 1.2 dB improvement in S/N can be realized by taking advantage of this. In addition, a portion of the transmitter deviation in the single channel case was attributable to the sound subcarrier which is not needed in the TCM case. If a 1.5 dB adjustment is made for this the result is:

single channel	two channel
S/N = 50.2 dB	S/N = 44.4

<u>S/N Enhancement</u> There is an additional step which we can take to improve the signal to noise ratio of the TCM system. Note that before each line of video is read into the common output line, the entire line is in storage. The maximum peak to peak amplitude of the line could have been determined as it was written into the store. This information can be used to increase the gain of the transmitter modulator and reduce the gain of the receiver video amplifier by equal amounts for any video line having less than the maximum allowable amplitude. The result will be no change in signal at the receiver, but the received noise will be attenuated.

This possibility is shown in block diagram form in Figure 4. Here the S/N enhancement circuitry has been shown separated from the TCM circuit. In this arrangement the incoming video signal is alternately stored in one of two stores.

As a particular line of video is written into storage, its peak to peak amplitude is monitored. As that line of video is read out of storage the results of the monitoring process is used to set a digital attenuator such that the amplitude of the line will be increased to the maximum which can be accepted by the transmitter. A code word to tell the receiving end of the system how to set its attenuator is inserted in the digital portion of the TCM format.

At the receiving end of the system, the sync timing and the instruction code words are recovered directly from the common line. An instruction generated from the code word is used to set a digital attenuator to remove the results of the extra deviation inserted at the transmitter. In doing this, it brings the signal back to the proper level and reduces the noise power introduced by the satellite link.

This enhancement process could, of course, be used in other applications such as line of sight microwave or video tape recording.

Figure 5 shows one attempt to divide video waveforms into categories which could be designated with a 4 bit digital word. The approach used here was to divide the problem into two parts. First, an off-set voltage was picked as the average amplitude of the signal measured from black level. Two bits were used to describe this off-set. Then, the peak to peak variation around this off-set was given a two bit designation. To use this with the signal enhancement circuit described the instruction generators at the transmitter and receiver ends of the system would control both a four level current generator and a four level digital attenuator.

The amount of signal to noise improvement which can be achieved with this circuit cannot be calculated. It must be determined through subjective tests. We have no reason to feel that a given amount of noise power will have an equally degrading effect in a high contrast portion of the picture and a portion of little contrast.

The circuit can,of course, remove much more noise power from a low contrast picture than it can from one with large changes of light level. It is interesting to note that for a video stream in which the wave forms shown in Figure 5 were equiprobable the measured reduction in noise provided by the enhancement circuit would be 5 dB.

A Video and Data Application The usefulness of the TCM approach is not limited to the transmission of two video programs over one transponder channel. In the example discussed, a digital stream representing two audio channels was interspersed with the two video signals. The different signal sources accommodated by a Time Compression Multiplex system may have greatly differing information rates. The time alloted to each source will be approximately proportional to its information rate. The system is flexible in that it can use different modulation processes to achieve different error performances for the various subchannels.

For example, a low data rate channel requiring excellent error performance might be handled as Binary Frequency Shift Keying. At some increase in error rate and a worthwhile improvement in signalling speed a channel could use Quaternary or M'ary FSK. For high values of M the channel error performance would be limited by phase equalization requirements unless a high correlation exists between adjacent symbols thus limiting the ringing or overshoot introduced by large transitions in a channel of poor equalization. It is the high intersymbol correlation of a video signal which allows us to increase M without bound and transmit video in its analog form on a TCM system.

To investigate the versatility of the TCM approach let us try to design a system which can intermix a standard video channel, its companion sound channel, and a low data rate digital channel (of the order of 10^5 bits/sec.)

Make it a further requirement that we be able to receive the digital channel with an inexpensive Receive Only Earth Station. The cost of an earth station for receiving satellite signals is determined by its G/T figure of merit. This term, usually expressed in dB/^{o}K is simply

$$G/T = 10 \text{ Log } G_{ANT} - 10 \text{ Log } T_S, \quad \text{where}$$

G_{ANT} is the power gain of the receiving antenna and T_S is the noise temperature of the system determined primarily by the input low noise amplifier used (LNA).

For a typical receive only video terminal using a 15 ft. dish and a 150^{o}K LNA the G/T rating would be 21.5 dB/^{o}K

To achieve a low cost receive terminal for our low data rate channel we would like to use a 4 ft. dish and perhaps a 750-1000^{o}K LNA. For this combination the figure of merit would be around zero dB/^{o}K.

Let us assume some system parameters and see how they affect the performance which can be expected. First assign to the video channel 3/4 of the available time and allow the remaining 1/4 for the data channel. This means that in the video receiver the top base band frequency will no longer be 7.87 MHz as it was in the example using two video channels. It will be reduced by a factor of 1.5/1 to 5.25 MHz. The noise performance of the video channel will be improved by 30 Log 1.5 for reduced base band frequency and by 20 Log $\frac{12.75}{10.13}$ for increased possible deviation. These combine to predict a S/N of 51.6 dB for the single channel with data compared to the 44.4 computed for two video channels.

Now let us select Quaternary Phase Shift Keying as a modulation method for the data channel. Allow a receive bandwidth of $B_{receive}$ where $B_{rec} = 0.75\ f_{data}$ and f_{data} is the data rate transmitted. Since data is only transmitted during 1/4 of the time

$f_{data} = 4 \times 10^5$ Bits/sec. for our assumed input data rate of 10^5 bits/sec.

The receiver bandwidth is

$$B = 0.75 \times 4 \times 10^5 = 3 \times 10^5 \text{ Hz}$$

Assume that the Quadraphase modulation is differentially coherent and that a carrier to noise ratio of 14 dB will give adequate error performance. We can now compute the required figure of merit for the data service ground station.

Recall that the carrier to noise ratio of a receiving earth station is given by

$$(6)\quad \frac{C}{N} = \frac{G}{T} - L_D - K + EIRP_{SAT} - 10 \text{ Log } B, \quad \text{where}$$

G/T is the receiving figure of merit
L_D is the total loss in the down link
K is a constant -228.6 dBW/°K
$EIRP_{SAT}$ is radiated satellite power, and
B is the receiver bandwidth.

For the video link we have been considering with B = 36 MHz, we assumed a C/N of 12 dB when G/T was 21.5 dB/°K.

For the same satellite, we can rearrange (6) to give the required figure of merit for our data channel as

$$(7)\quad G/T = C/N - 66 + 10 \text{ Log } B.$$

From this we have

$$G/T = 14 - 66 + 54.77 = 2.8 \text{ dB/}^\circ\text{K}.$$

To use a 4 ft. receiving dish, we would need a 750° K LNA.

Figure 6 shows the block diagram of a combination video and data system using TCM. Since different types of modulation are proposed for the two different kinds of input, the two streams are essentially separate until they feed a final transmitting amplifier. Both of the streams use angle modulation.

There must be one connection between the two streams having to do with timing. It would probably be easiest to take system timing from the video side. This might cause some buffering problems on the data side which would require pulse stuffing to adjust the data rate to go with a store switching time set by the video.

At one receiving site a small dish and a narrow band receiver would receive the data signal. A number of possibilities exist for recovering timing. Recall that the beginning of the data stream of interest corresponds to switching off a FM signal which was shifted to a frequency representing black level of the video and switching on a DQPSK signal centered in the receiver pass band.

This should afford a start toward achieving a sync signal.

There is no particular requirement that the data subchannel be located in the center of the transponder passband. The location of a data subchannel might well be chosen to avoid interference from a similar channel on the same transponder channel of an adjacent satellite.

At a second location a larger dish and a wide band receiver are used to recover the video traffic. Analog stores spread this time compressed signal and deliver it at a real time rate to the output line.

Two Way Application In the previous example, the actual interleaving of the signals took place when they were in radio frequency form on their way to a transmitter. The signals were actually separated in the radiation downlink from the satellite. By an extension of this idea we can use TCM to achieve two way video communication via one satellite channel.

There are two sets of timing requirements. The first stems from the fact that the two signals are completely independent in timing. The other from the fact that the transmission paths via the satellite are not fixed in length. To solve both of these, we start by nominating one video source as master and the other as slave. As shown in Figure 7, we locate a receiving ground station at the slave (B) location. At the master station, we transmit time compressed bursts of A video starting and stopping during blanking interval. Station A's transmission must have with it a digital group for audio and sync purposes.

At station B, we receive A's transmission and compute when B's transmitted burst would have to occur to fit on an interleaved basis. A time guard band must be provided to accommodate motion of the satellite relative to the two ground stations. We have two options to make provisions for B's commutating switch. A time base corrector can be used to GenLock B video to A video. It does this by storing a video frame and adding or deleting a blank line during the vertical interval as necessary to accommodate absolute differences in sync frequency. This is an expensive device, and it may be preferred to simply increase slightly the time guard band allowed and transmit extra B samples to avoid crosstalk from the commutating switch. The total guard band time allowed must take into account the fact that the time delay introduced in the transmissions from both stations is not constant. The satellite may be moving toward station A and away from station B. In this case the transmission from A will appear to arrive too early and that from B, too late. The time guard band must be large enough to prevent the last part of a B transmission from overlapping the start of an A transmission. This requirement is relatively easy to meet. A more severe requirement is that between one transmission burst and the next, the distance should not change enough from either station to alter the phase of the recovered color subcarrier more than some acceptable amount.

The distance from an earth station to a satellite of relative longitude L and latitude H is about

$$r = 26500\,(1-0.295 \text{ Cos H Cos L})^{1/2}.$$

If the satellite is at $H = 30^\circ$, $L = 50^\circ$, and it changes station by 0.1°, its distance will change by about 7.5 miles. For a satellite which keeps station to $\pm 0.1^\circ$, the worst case change of range will be 15 miles and the change in difference of distance from two earth stations will be about 5 miles. Thus, the worst case change in loop delay is 160 microseconds, and for difference in delay, the change is 27 microseconds. If the satellite drifts through its extreme positions in a one hour period, the rate of change of loop delay is 4.4×10^{-8} sec/sec. and the rate of change of delay difference is 7.5×10^{-9} sec/sec.

The rate of change of loop delay controls our ability to achieve proper color synchronization by sending a burst of color carrier once per field. With the rate of change of delay computed above, the color carrier would shift in phase by about 1° in 1/60 sec.

The rate of change in delay difference controls how much the time guard band between two interleaved transmissions can change in the time required to send a signal up to the satellite and get a reply back. This time is about 0.28 seconds, and in that time the delay difference could have changed by about two nanoseconds for the example given.

Conclusions The Time Compression Multiplex System described here is in a developmental status. A number of possible configurations must be built and tested before its full potential will be known. Subjective tests of picture quality in the laboratory and transmission tests over satellite paths must both be made before system parameters can be finalized.

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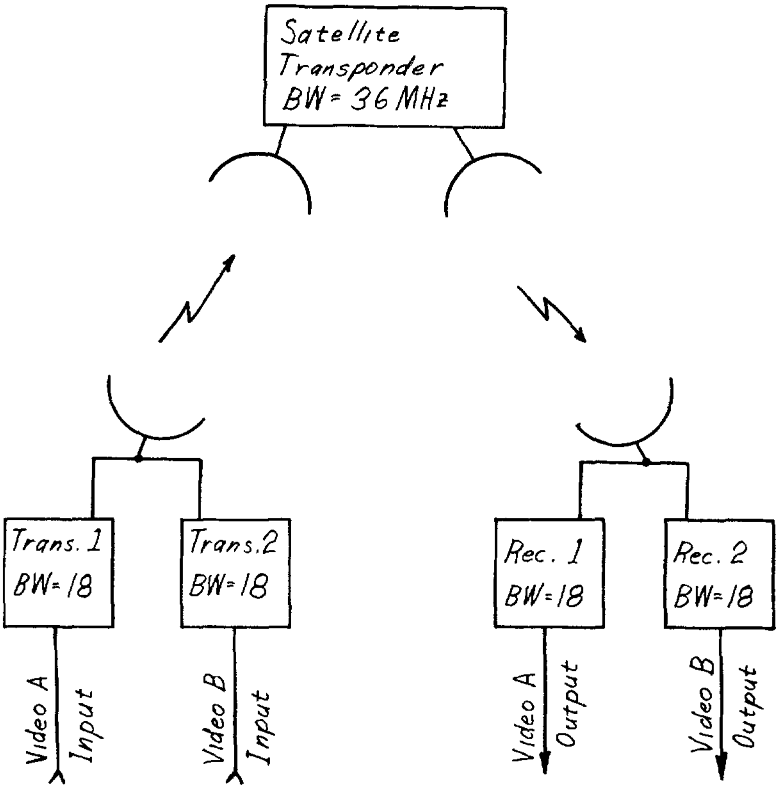

Fig. 1 Frequency Division Multiple Access

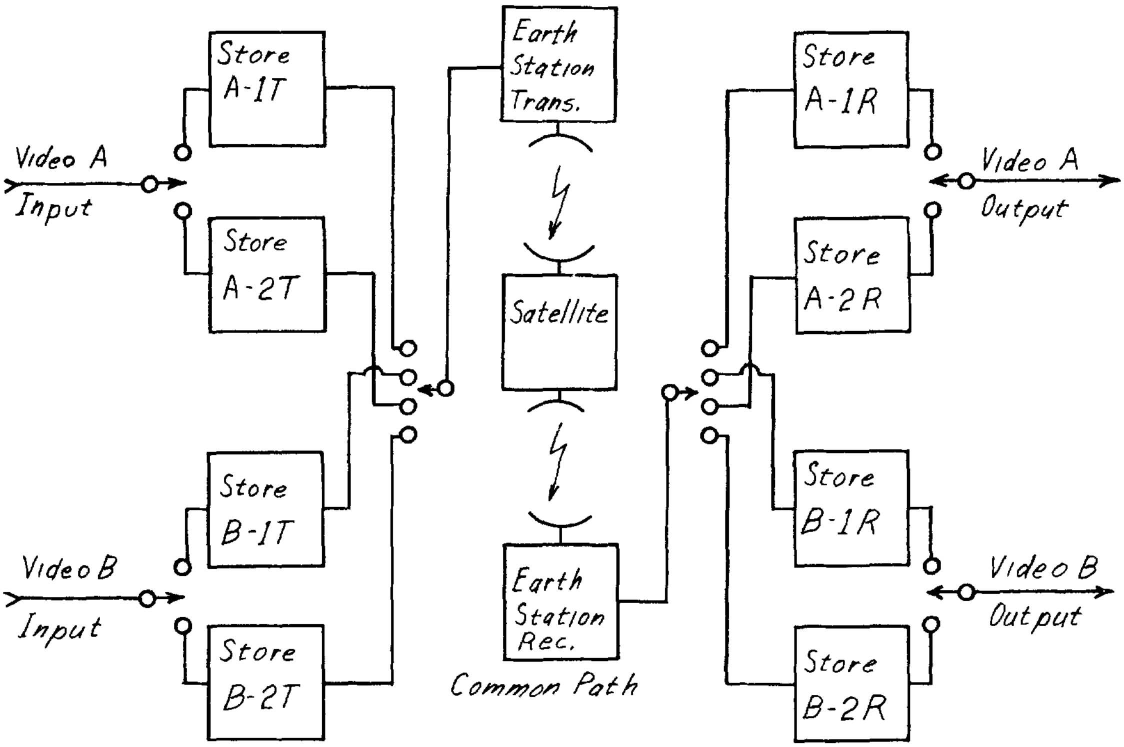

Fig. 2 Time Compression Multiplex System

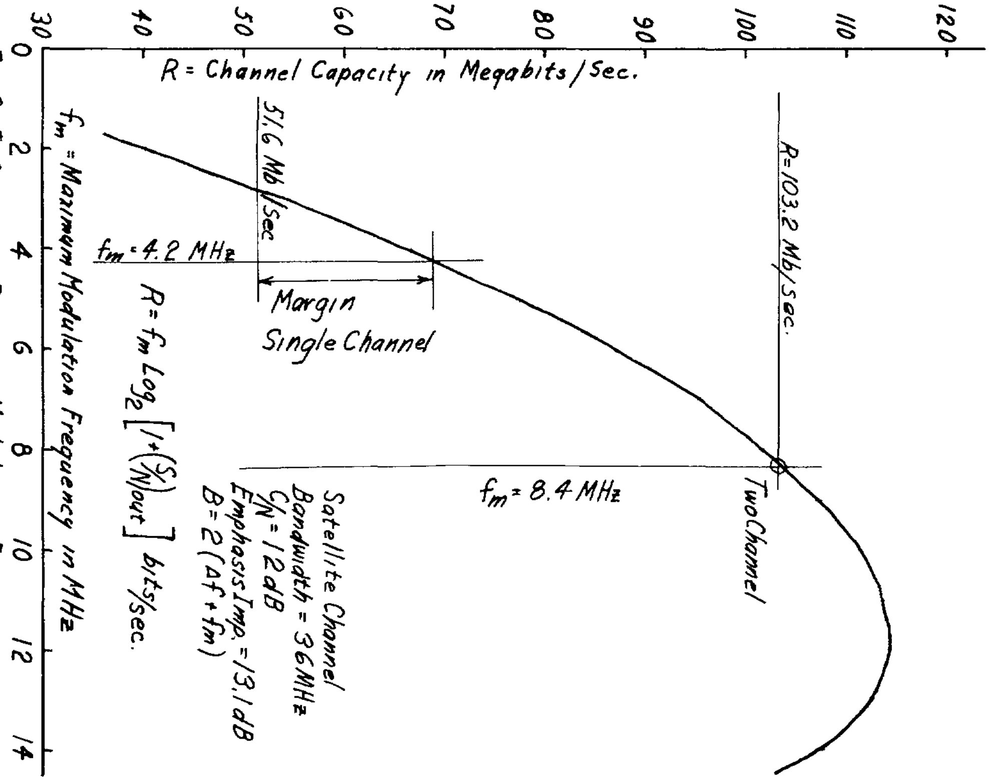

Fig. 3 Information Rate vs. Modulation Frequency

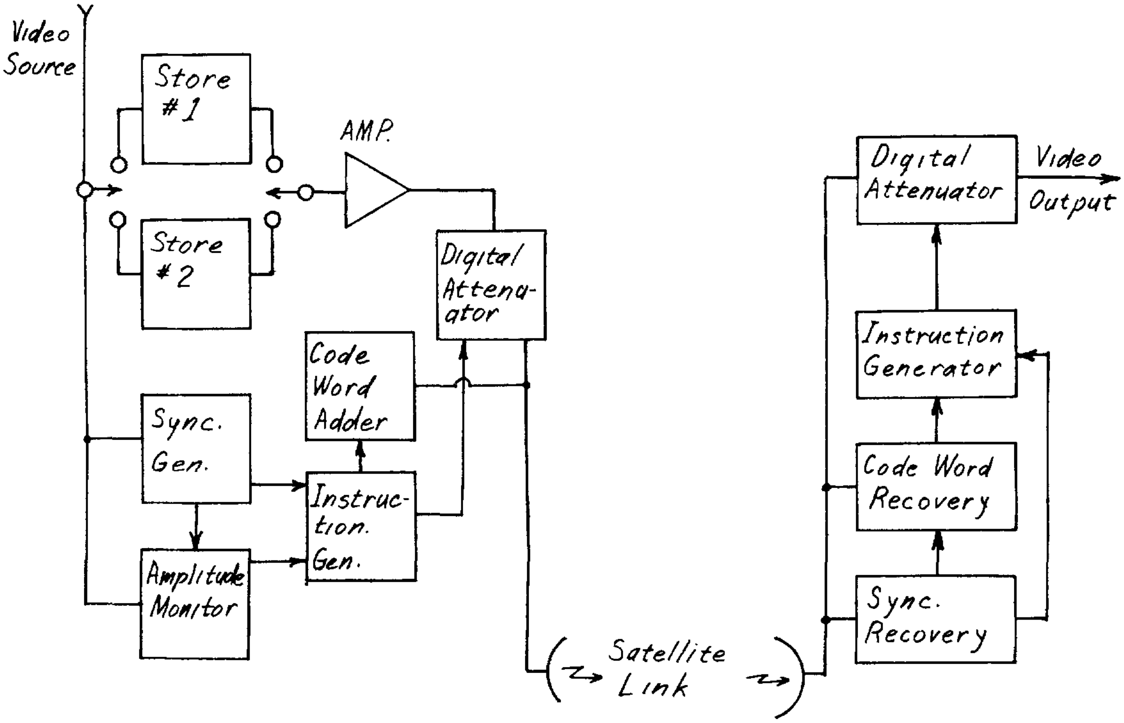

Fig. 4. S/N Enhancement Circuit

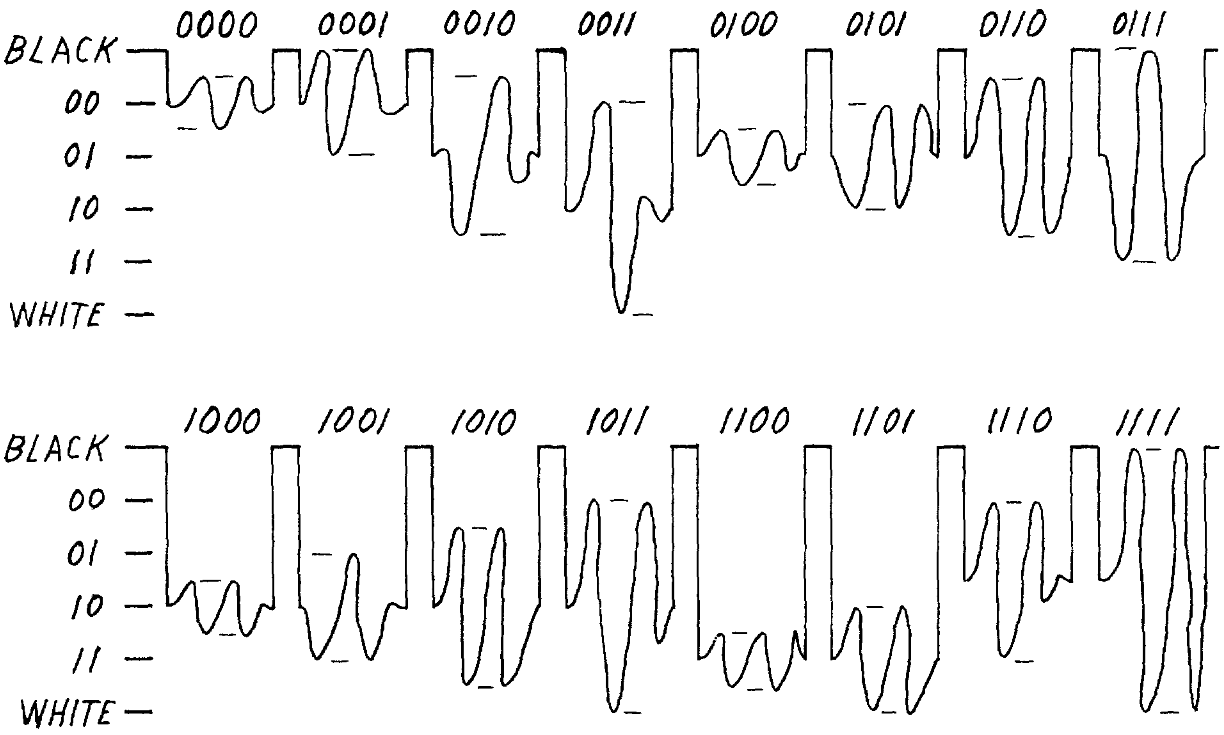

Fig. 5 Video Signal Catagories With 4 Bit Designations

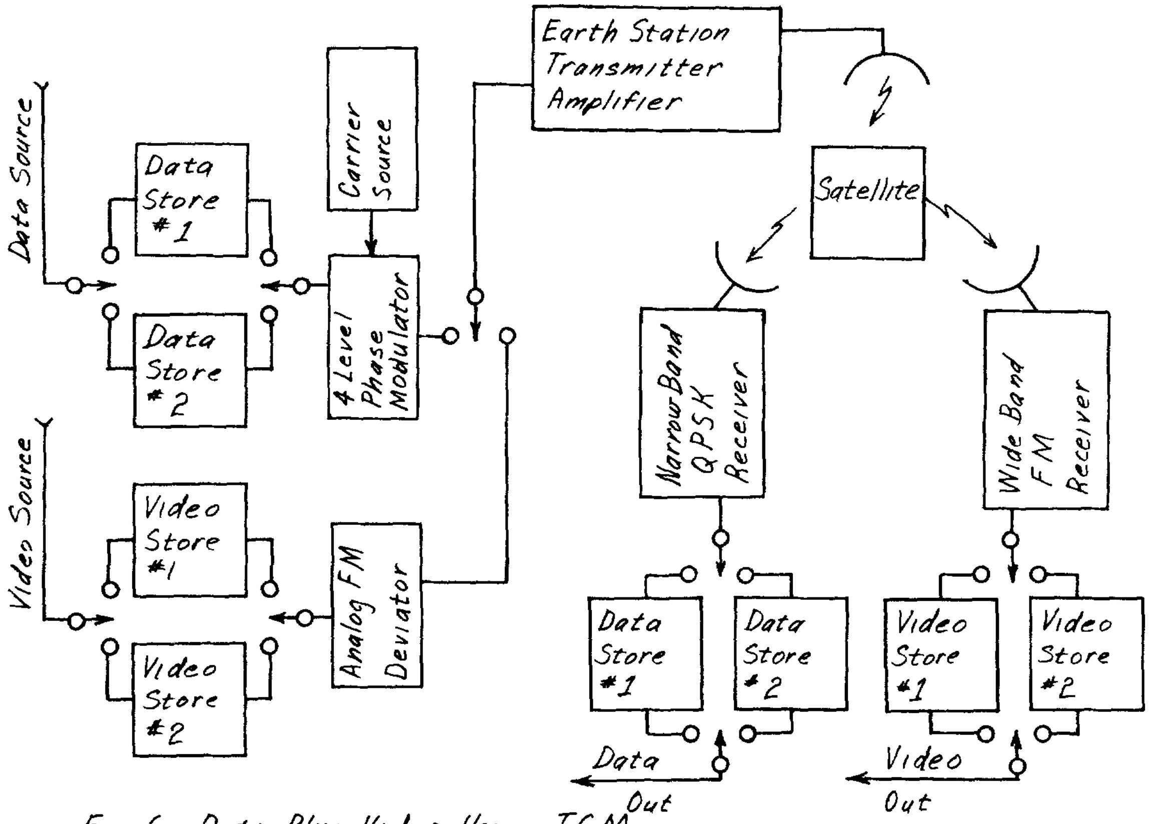

Fig. 6 Data Plus Video Using TCM

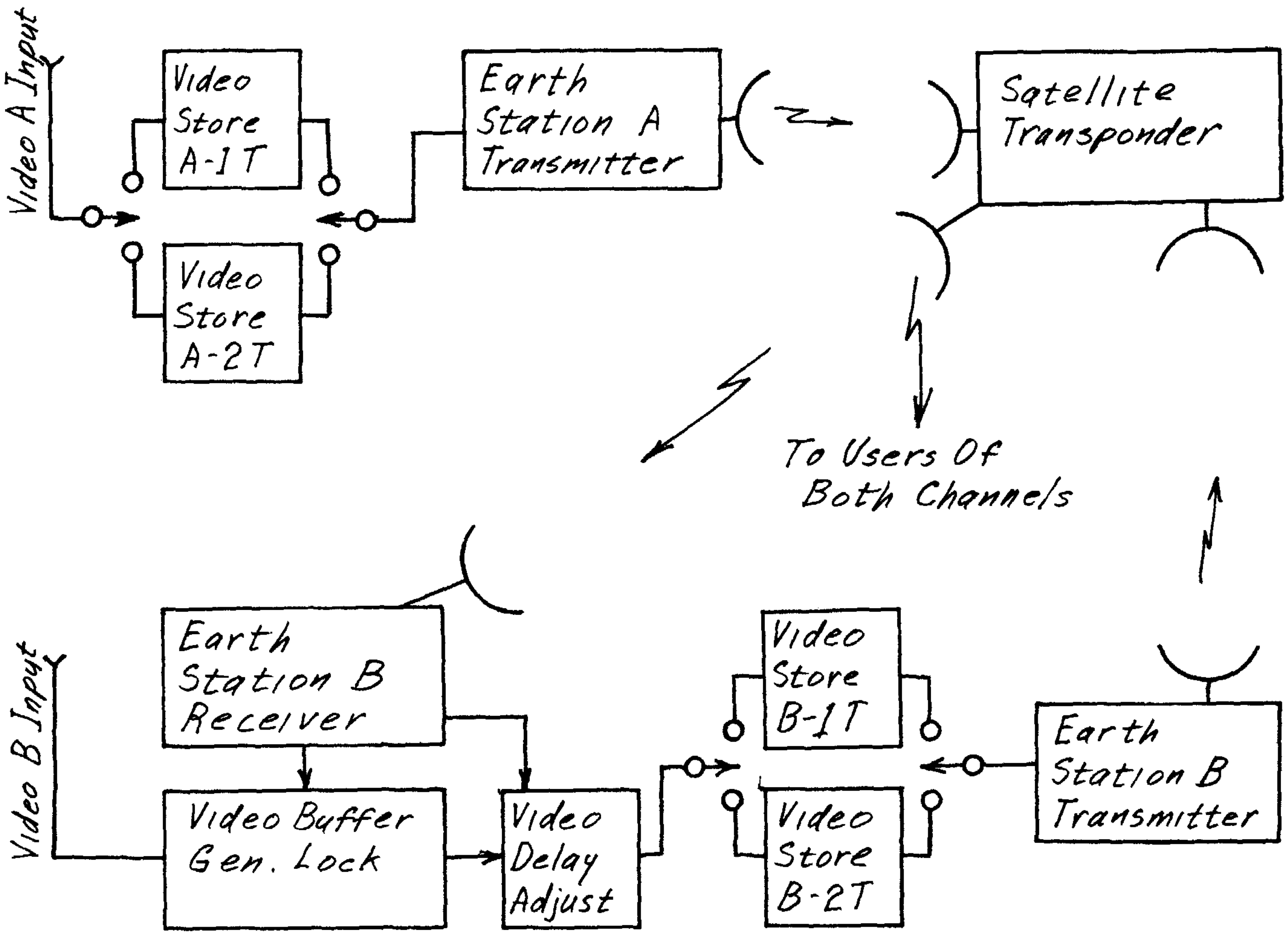

Fig. 7 Two Way Video Transmission Using TCM

AGC/ASC DESIGN

Bert Arnold

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Abstract

A unique AGC/ASC design which is capable of being cascaded in every amplifier in a CATV system without the problems associated with conventional AGC/ASC design is discussed. A conventional AGC/ASC design is compared to the new design by use of block diagrams and each function of the AGC/ASC is discussed. Finally, the measured results of the cascade performance is given.

Introduction

CATV systems require automatic gain and slope controls to compensate for cable changes due to temperature variations. The AGC in an amplifier samples the level of a reference carrier and corrects the gain of the amplifier to compensate for any level change. Over the past years, the cable industry has switched from using CW carriers for these reference carriers, to video modulated carriers and back again. There are some problems that can be encountered by using cascaded AGC/ASC's, which have caused this indecision on the use of CW or modulated pilot carriers and also whether AGC/ASC should be used in every position, every other, or every third position.

This paper discusses some of these problems associated with cascaded AGC/ASC's and presents an AGC/ASC design which overcomes these problems.

AGC/ASC

A conventional AGC/ASC design used in the cable industry is shown in Figure 1. The RF signal is sampled at the output of the RF amplifier by a directional coupler and filtered by a bandpass filter. The RF signal is then amplified, detected, and compared to a DC reference voltage to provide a correction voltage to the voltage controlled attenuator. A low pass filter after the DC amplifier filters any low frequency components which might modulate the control voltage. The low pass filter is usually a single pole filter (one capacitor to ground) to ensure stability of the AGC loop. If a CW pilot carrier is used, the filter capacitor does not have to be very large as long as the pilot filter on the input of the AGC is sharp enough to reject the adjacent channels. If modulated pilot carriers are used, the filter capacitor must be large enough to reject the low frequency components that are present in the modulated video (transfer modulation) of the pilot carrier or adjacent channels. Increasing this filter capacitor causes the time constant of the AGC/ASC loop to increase. This large time constant makes the system AGC difficult to set up and results in a long settling time for the system following a transient in this pilot signal or an adjustment of the AGC controls. In order to overcome this problem, systems using this conventional type of AGC/ASC will compromise by minimizing the number of AGC/ASC's, placing them in every other, or every third trunk station.

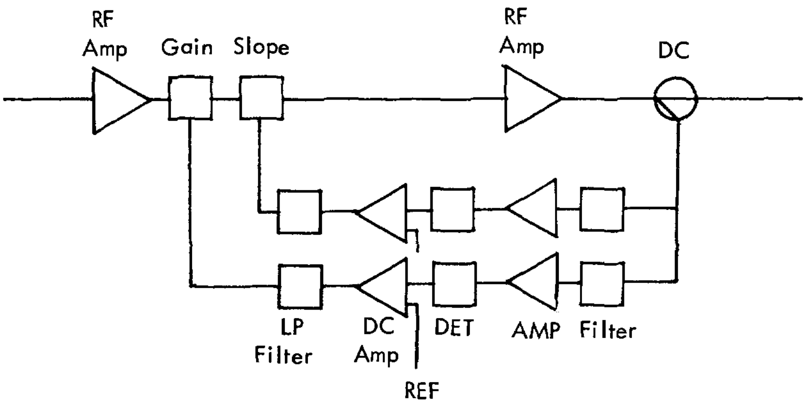

FIGURE 1

A cost savings is also claimed for this type of system using a minimum number of AGC/ASC's. The opposite is true in cases where the temperature change is large. In order to achieve the same performance with AGC/ ASC in every amplifier, the system with AGC/ASC in every other position would have to operate at a lower level to allow for the variations due to temperature in the non-AGC amplifiers The lower output level would result in more amplifiers per mile at a total system cost exceeding the cost differential between AGC/ASC in every trunk station versus every other station.

RCA-AGC/ASC

RCA has designed an AGC/ASC which minimizes cascade instability resulting from a long time constant and minimizes the transfer modulation resulting from low frequency components of the video modulation. This design allows for maximum utilization of AGC/ASC's in a system for maximum performance. A block diagram is given in Figure 2 of the RCA-AGC/ASC.

RCA's AGC/ASC is designed using video detection techniques which eliminate the need for the large filter capacitor in the low pass filter. This design allows for a relatively fast time constant, excellent filtering for adjacent channel rejection and provides a high detector voltage for stability. The following is an explanation of the block diagram in Figure 2:

Hybrid Amplifiers A1 and A2 -

The hybrid amplifiers are wideband RF gain blocks within the CATV amplifier.

Gain and Slope Controls -

The signal, after being amplified by hybrid #A1, passes through a gain and slope control. These controls are a voltage controlled attenuator and variable equalizer, respectively. The AGC/ASC provides the required voltage for controlling the gain and slope of the amplifier.

Directional Coupler -

A high value directional coupler samples the level of a reference carrier at the output of the second hybrid module. A high value (15 dB) DC is used to minimize insertion loss in the output of the amplifier and to isolate the AGC/ASC from the main trunk line.

Attenuator -

The sampled signal is then passed through an attenuator. With normal signal levels in a system, this attenuator is not used. The purpose of the attenuator is to provide a wide dynamic range to the AGC/ASC for special applications. If the amplifier should be used as a transportation trunk, carrying a few channels, the levels in the trunk could be raised to improve the carrier-to-noise ratio. The sampled signal to the AGC/ASC may then be reduced by the input AGC/ASC attenuator for proper operation.

Buffer Amplifier -

The sampled signal is amplified by a wideband RF amplifier. This amplifier provides a portion of the required loop gain while increasing the isolation between the AGC/ASC filters and the main trunk line.

Pilot Filters - No. 1 and No. 2 -

The pilot filters select the pilot frequencies that will be processed to control the gain and slope of the amplifier.

RF Amplifier -

The pilot signals are further amplified by a wideband amplifier before a second set of pilot filters separate the gain and slope frequencies into separate paths. From this point, the AGC and ASC circuits are almost identical, so this description will be of the lower AGC circuit in the schematic.

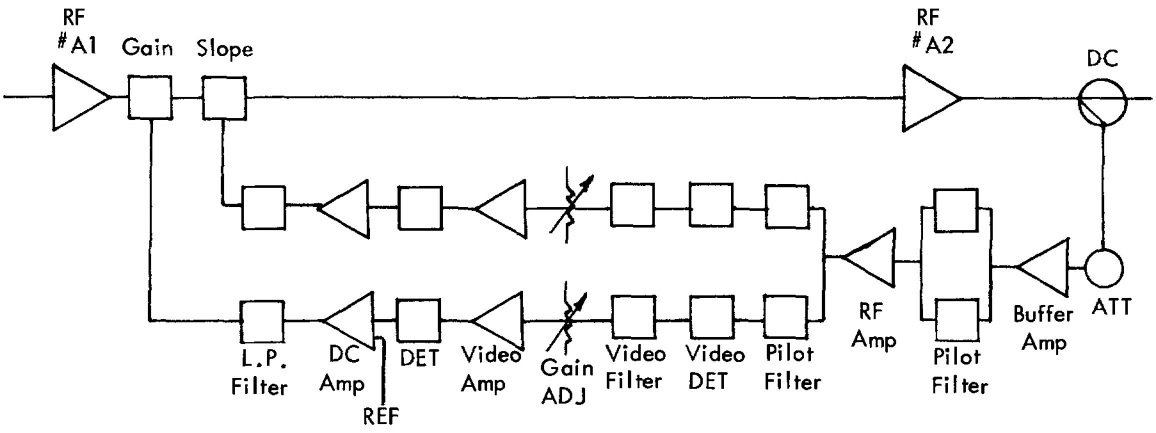

FIGURE 2

Video Detector -

If the pilot signal is a CW signal, the output of the video detector will be a DC voltage that is proportional to the amplitude of the RF signal. If the pilot signal is a modulated television channel, the video detector output will be a sync-positive video signal with the DC level of the sync-tips proportional to the level of the RF signal.

Video Filter -

The video filter limits the video bandwidth and filters out any RF components. Filtering in the video domain minimizes the effects of adjacent channels on the pilot channels with a relatively small filter capacitor. As a result, excellent filtering is provided with greatly increasing the time constant of the AGC loop.

Gain Adj -

The "Gain Adj" selects the required video level to produce the module AGC output voltage that is required by the trunk module.

Video Amplifier -

The video signal is amplified by an integrated circuit video amplifier to provide a high voltage (6 volts) to drive the following peak detector. By amplifying the AGC signal in the video domain, a more stable amplifier relative to RF gain, can be achieved. The high voltage driving the peak detector assures that the detector diode is operating in the most linear and stuble region, and the amplified sync-tips minimize the effect of the video information on the AGC loop.

Peak Detector -

The peak detector detects the peak of the video signal, or the sync-tips, in the case where the pilot frequency is modulated. It passes the DC signal resulting from a CW pilot frequency.

DC Amplifier -

The detected signal is then compared to a reference voltage and amplified.

Low Pass Filter -

With the filtering and processing done on the video, the requirement for a large filter capacitor to filter the modulated signal is not necessary. A nominal amount of filtering is used to attenuate any frequency components above the DC control voltage. The resulting DC control voltage drives the gain control to correct for any level change in the system.

Cascade Performance

A cascade of RCA Model 151 Amplifiers was tested to verify the stability and practicality of using AGC/ASC in every amplifier position for maximum performance and economy.

Figure 3 is a plot of the amplifier reaction time when the pilot level was stepped $\pm$ 2 dB. The figures show that overshoot and undershoot are present in cascaded AGC's when pulsed, but the time constant of this transient is 50 to 100 times faster than conventional AGC/ASC's (0.3 sec). This fast time constant minimizes any system instability due to transients or field set up adjustments and allows AGC/ASC to be used in every amplifier station.

The pilot signals for gain and slope were also turned off and on with settling times being the same as shown in Figure 3.

Both adjacent channels to the pilot channels, were switched on and off with less than a 0.1 dB change in the pilot level. The modulation was also switched on and off the pilot channel with less than 0.1 dB change in pilot level. This stability in the pilot level is a result of the video processing and peak detection in the AGC/ASC as discussed above.

SUMMARY:

1. AGC/ASC should be used in every trunk amplifier in a system to achieve excellent performance and economy.

2. Video processing and peak detection in the AGC/ASC minimizes the effects of adjacent channels, modulation, and other low frequency components.

3. Short time constant allows system to be easily set up because of the fast settling time and greatly reduces the duration of any transients.

4. Reliability of the total system is improved with AGC/ASC in each amplifier. If an AGC/ASC module should fail, the system will have the AGC/ASC range to make up for the failure before the system experiences any overload distortion.

AGC RESPONSE TO ± 2 dB STEP

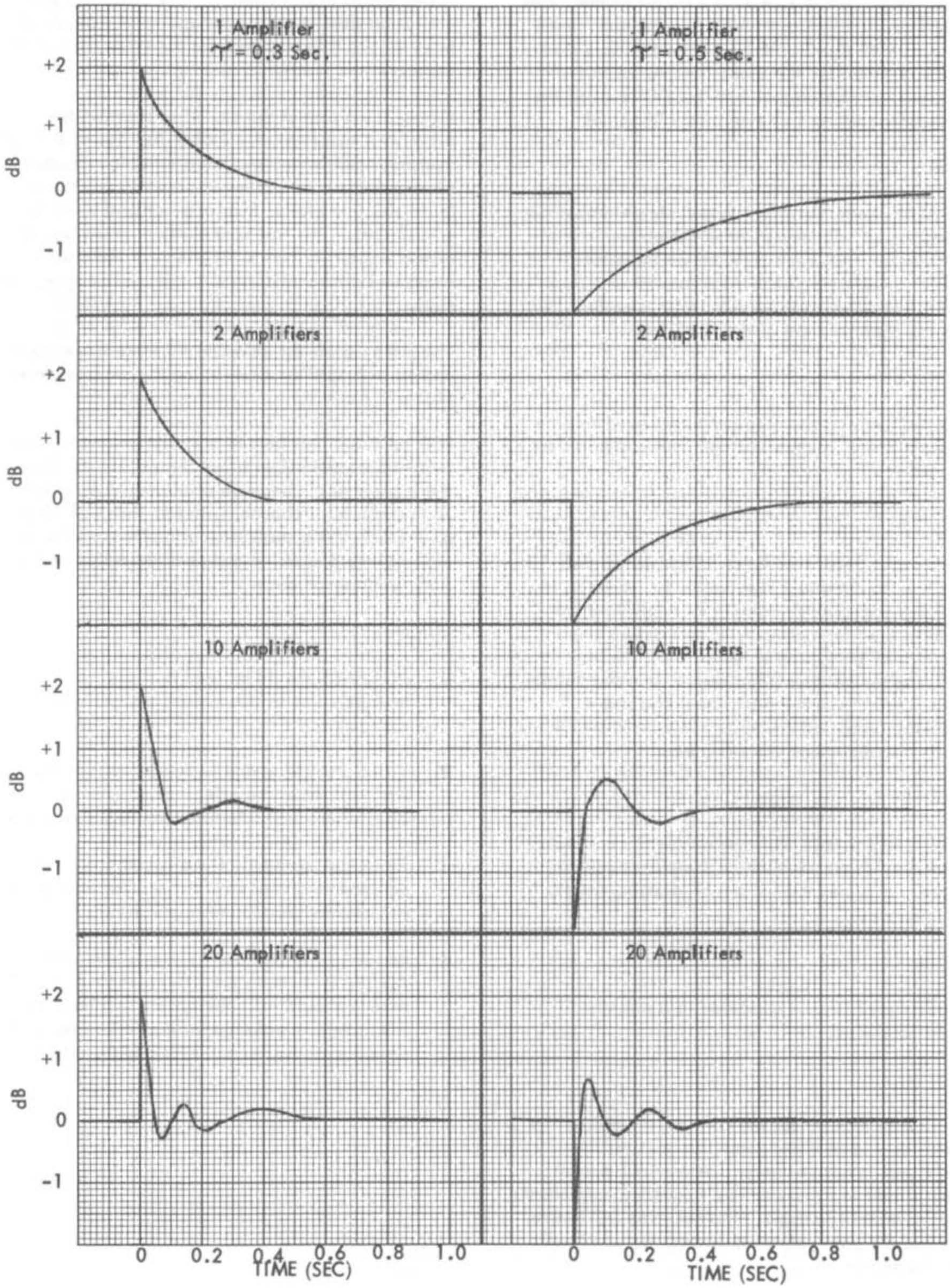

FIGURE 3

"AN 8 KM FIBER OPTIC CATV SUPERTRUNK SYSTEM"

By

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Donald G. Monteith
Cablesystems Engineering, London, Ontario, Canada

ABSTRACT

The technical criteria for the design, analysis and hardware implementation of the first major fiber-optic digital CATV supertrunk in North America are presented.

The supertrunk system transmits 12 NTSC color television channels and 12 FM stereo channels over an eight-fiber cable 7.8 km in length. The optical fiber cable is lashed to messenger wires with optical repeaters at 2.8 km intervals. Audio, video and FM signals are digitized and multiplexed into a single 322 Mb/s bit stream modulating an injection laser diode transmitter.

1.0 INTRODUCTION

Fiber optics technology has made its debut from the laboratory to operating hardware in dramatic fashion this past year.

Major telephone companies have installed operational interoffice trunking in large cities in the U.S., Japan, and Europe. Utility firms have installed data transmission systems using optical fiber systems.

The cable television industry has also shown a high degree of interest in fiber optics systems as a possible means of increasing subscriber options through two-way telecommunications services, higher reliability and service to peripheral areas previously not cost-effective to serve. In addition, the economic projections of smaller cable, fewer repeaters, lower maintenance costs and lower capital investment have intensified CATV interest.

A wide variety of papers have been published by others speculating on what fiber optics might do for the CATV industry. This paper will describe actual fiber-optic system hardware built for a specific CATV application, i.e., a 7.8 km fiber-optic digital television trunking system. Applications to the general trunking problem will become apparent as the system is described.

2.0 SYSTEM DESIGN CRITERIA

An optimal fiber-optic trunking system is directly dependent on the trunk variables of length and performance specifications. Extensive analytical studies were done on this particular link, which carries 12 channels of color television and 12 FM stereo channels from the headend studio location to the hub distribution node. The studies made use of computer models for the transmission link using various modulation schemes.

The results of these studies showed that for a trunk length of less than 8 km, only two repeaters would be required in the link to provide studio quality video reception. The optimal modulation scheme was shown to be digital pulse code modulation (PCM) for this link, providing the best overall technical-cost performance.

An important consideration in the system design was the potential for hardware simplification offered by a fiber-optic digital repeater over conventional analog repeaters. Repeaters can be reduced to simple optical-to-electrical (and back again) regenerators for binary signals. Further, previous problems such as accumulation of intermodulation distortion (IMD) products through cascaded analog repeater chains do not exist for digital PCM video transmission systems. While such problems have limited the length of analog trunks, digital trunks have no such limitation. The net result favors digital transmission methods by providing less complex repeater modules, higher reliability, lower system maintenance costs and the potential of very long trunk lines.

2.1 System Trade-Offs

Fiber-optic repeaters can be spaced at intervals of 3 km or more, depending on fiber attenuation and dispersion characteristics.

This fact is important because fiber-optic trunk lines can reach 5 to 6 times as far as conventional coaxial systems before repeater units are required. Fiber-optic repeater lines up to 1000 km long are presently under serious consideration by major operating telephone companies.

As a general rule, fiber-optic repeaters require digital retiming (bit synchronization) in each unit to correct for the accumulation of bit errors through cascaded repeaters. For the particular 7.8 km trunking system described in this paper, analysis showed that link retiming could be accomplished effectively in the hub terminal equipment alone, and would not be necessary in the individual repeaters. Thus further equipment simplification and lower parts count were made possible in the repeater units, providing increased reliability. The overriding design goal was to design the optical repeater units as simply and straightforward as possible, since they are pole-mounted and operate in a more severe environment than the headend and hub terminal equipments.

Another important system design consideration was the trade-off of two candidate types of television signals to be encoded and transmitted, i.e., baseband video signals or vestigal sideband (VSB) signals. One well-known method of transmitting television signals is to digitally encode the baseband video, separately encode the program audio, and then combine the two data formats digitally into a single digital bit stream.

A second method of transmitting television signals which is particularly attractive to CATV applications, is to digitally encode the entire vestigal sideband spectrum. Since the VSB spectrum includes audio, picture and color subcarriers, it offers the potential of significant headend equipment cost reductions for new or updated installations.

Table 1 lists the major benefits and disadvantages of both video encoding methods. Both methods of video digitization are provided in this system to permit field tests of both implementations, on a side-by-side basis with each other and also with a conventional coaxial analog supertrunk.

Table 1. Trade-Off of Baseband Versus VSB Video PCM Encoding Methods

Baseband Video Encoding

Advantages	Disadvantages
• Lower Link Costs (3 TV channels per fiber)	• Higher Fixed Terminal Costs ("off-air" signals require demodulation to baseband)
• Lower Encoding Electronics Cost	• Total Interface Cost 3 to 4 Times Greater Than VSB Encoding

VSB Video Encoding

Advantages	Disadvantages
• Lower Fixed Terminal Costs (no demod/modulator required)	• Higher Link Costs (2 TV channels per fiber)
• Lower Total Interface Cost (direct VSB encoding)	• Higher Encoding Electronics Cost

The variables shown in Table 1 can be separated into two cost factors, fixed terminal costs and variable link costs. Fixed costs depend on the specific choices of headend and of terminal distribution equipment. Variable link costs depend on the total trunk length and the number of repeaters and fibers used in the link. Using 1981 cost projections of fixed and variable costs for both baseband and VSB PCM encoding equipments, it can be shown that the total cost of a VSB link is less than the total cost of a baseband link, if the total length is less than 20 km. In other words, two channels per fiber VSB PCM is more cost-effective than three channels per fiber baseband PCM for distances less than 20 km, because the additional terminal equipment cost for the three channels per fiber case is not offset by variable link costs until the link length exceeds 20 km.

3.0 DESCRIPTION OF THE SYSTEM

The telecommunications system described in this paper uses graded-index optical fibers having a bandwidth-distance product in excess of 600 MHz-km and attenuation less than 8 dB/km. Eight small optical fibers (0.005-inch diameter) are formed into a single multifiber cable providing transmission capacity for a full 12 TV channel supertrunk in a cable less than 1/2-inch in diameter.

Of the eight fibers, only six are actively used, allowing the two spare fibers to be used for expansion to 18 channels. The six fibers are allocated as follows:

Fiber No.	Function
1, 2	Each fiber carries three high-quality digital baseband TV channels, three digital FM stereo channels plus parity and housekeeping data.
3, 4, 5	Each fiber carries two high-quality digital VSB TV channels, four digital FM stereo channels, plus housekeeping data.
6	Fiber carries three channels of high-quality digital baseband in the opposite direction (i.e., from distribution hub to headend)

Thus the system provides for full duplex (two-way) video communication.

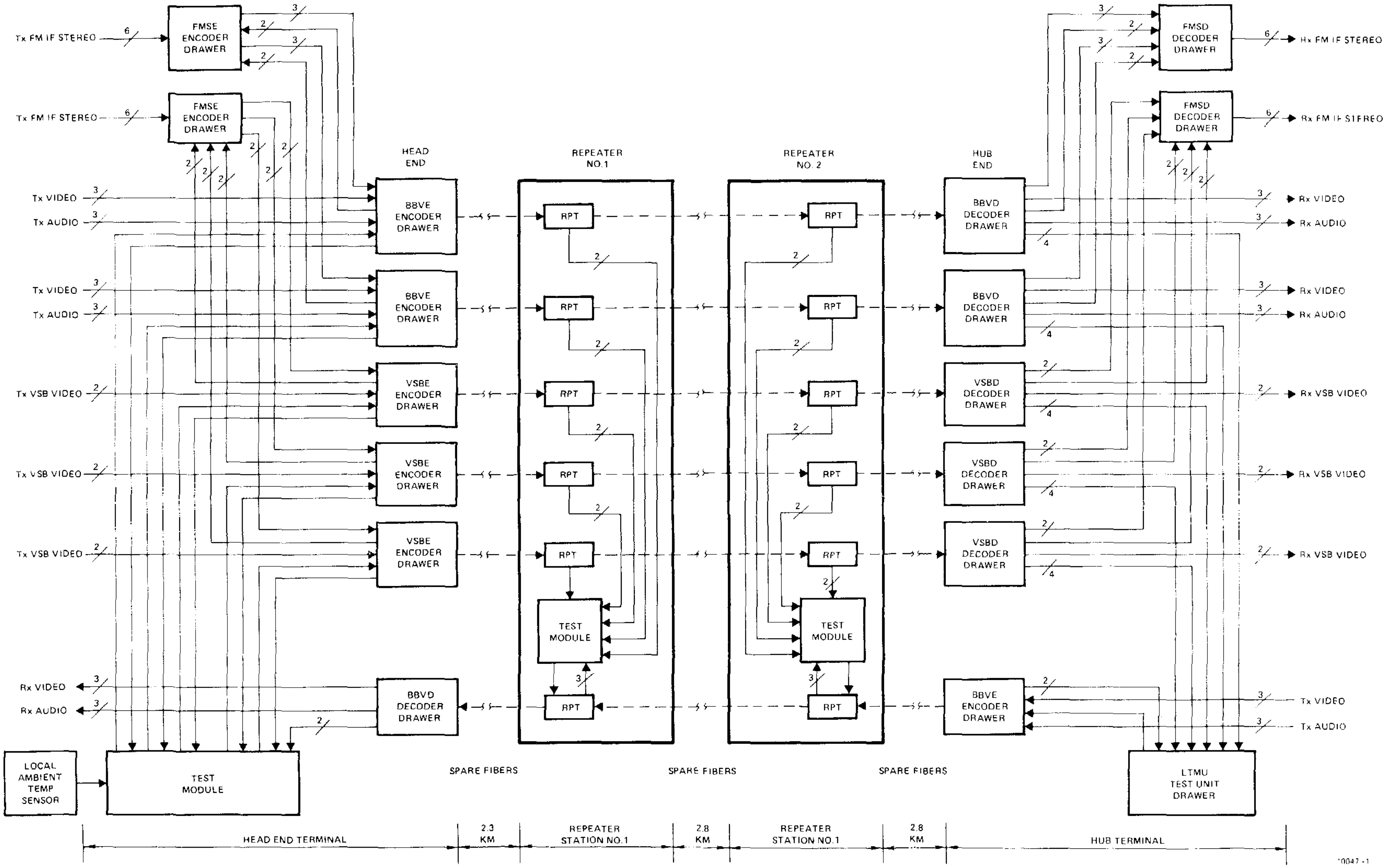

Figure 1. Fiber-Optic Supertrunk Link Block Diagram

The total system length selected for this system is 7.8 km, the distance between the head-end terminal location and the hub distribution location.

A block diagram of the system is shown in Figure 1.

3.1 Baseband TV Processing

In order to transmit studio quality signals, a baseband encoded digital TV signal requires 8 bits sampled at or above the Nyquist rate. The sampling rate was chosen at 10.74 MHz, the third harmonic of the color subcarrier frequency. An additional ninth bit is required for multiplexing the audio portion of the signal and for carrying the frame synchronizing data. A tenth bit is used for a parity bit for error detection and concealment to reduce the effect of bit errors on decoded video quality. With this data format, each single baseband TV signal produces a 107.4 megabit per second (Mb/s) digital bit stream.

Three such digital bit streams are then multiplexed into one serial bit stream at 322.2 Mb/s, which is in turn transmitted over the fiber-optic link. The FM stereo bits are interleaved into the bit stream into spare time-division multiplexed timeslots.

3.2 Vestigal Sideband Processing

The VSB encoded TV signal is encoded in a similar manner to the baseband scheme previously described, but is sampled at a higher sampling rate of 16.1 MHz because of its higher analog bandwidth. The VSB digital data format produces a bit stream at 161.1 Mb/s. Two such bit streams are interleaved into one serial bit stream at 322.2 Mb/s for transmission over the link.

3.3 Fiber-Optic Link

The system uses injection laser diode (ILD) transmitters and avalanche photodiode (APD) receivers at both ends of the link as well as in repeaters.

A block diagram of the ILD transmitter is shown in Figure 2. The transmitter outputs 322 Mb/s NRZ digital code in optical form, giving over 1 mW of optical power into the fiber. An optical feedback circuit controls and stabilizes the laser threshold over temperature and time variations.

The APD receiver is shown in Figure 3. The optical fiber stub terminates on the face of the photodiode, the output of which is amplified by a wideband, high-gain RF amplifier with AGC.

The fiber-optic link was designed to provide an overall end-to-end system BER of better than one error in 10^9 bits (BER $< 10^{-9}$) at a data rate of 322 Mb/s. Actual BER performance has been measured at better than 10^{-10}, which is the limit of the present test equipment.

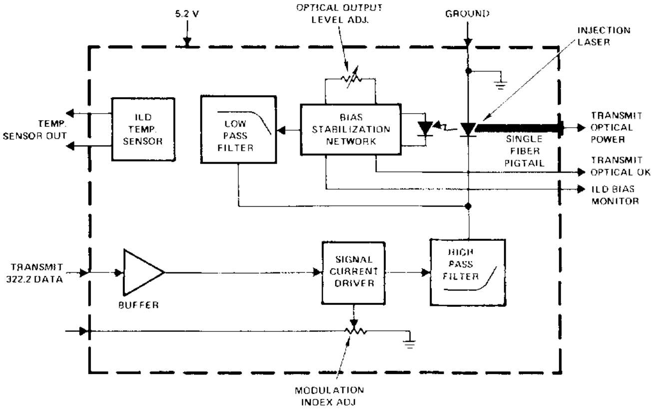

Figure 2. Injection Laser Transmitter 322 Mb/s

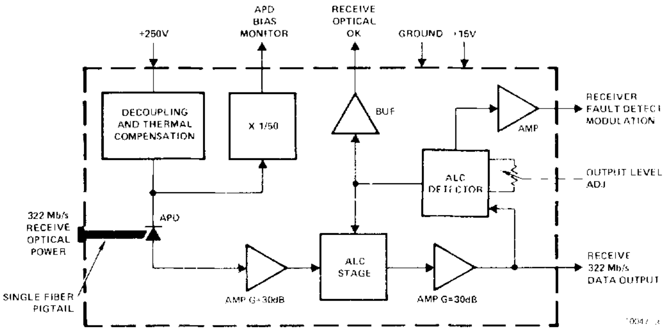

Figure 3. Avalanche Photodiode Receiver, 322 Mb/s

Additional "safety margins" have been incorporated in the system design to ensure that the bit-error rate never limits system performance. For example, a parity detection circuit was designed into the system to search for bit errors in the four most significant bits of the digitized video sample. A logic processor stores the third previous video word to minimize changes in chrominance and luminance coherency, and the current word is checked for parity error. If an error is found, the previous correct sample is used, and the present erroneous sample is discarded. In effect, this technique of error detection and concealment allows errors to be located and removed prior to transmission to system subscribers. The result is a greater improvement in video service quality and reliability.

Another safety feature of the fiber-optic link is optical power margin, or link margin. This is the extra allowance made for equipment aging, variations in optical power, lossy fiber splices, and general time-variant system parameters. The link margin for this supertrunk system is 10 dB, which indicates that a significant optical link degradation can occur over time without the bit-error rate falling below the system BER specification of 10^{-9}.

It might be observed that the system appears to be "overdesigned" for the intended purpose as a CATV supertrunk. Previous work published in the digital video field (by SMPTE and others) has established that a BER of 10^{-7} or less will have no perceptible effect on the quality of the digitally transmitted video. One might next ask why, then, was the system designed for 2 to 3 orders of magnitude better BER performance than required?

The answer lies in the basic need for the CATV industry to accept a more universal view of the tremendous telecommunications potential of fiber optics trunking systems to include other broadband communications services. Data communications, computer and satellite interconnects, two-way telephone trunking, teleconferencing and "wired city" concepts are but a few of the myriad of telecommunications applications effectively addressed by fiber optics. Most of these services are more sensitive to bit-error rate than is digital video, and the specified system BER of 10^{-9} can readily accommodate each of these services.

Some of the excess bit capacity in the system has been specifically dedicated to permit such external synchronous or asynchronous digital data services to be transmitted over the supertrunk link, in addition to the normal video, audio and FM stereo channels. Each Baseband Video Encoder drawer, for example, can accept up to 30 synchronous CVSD [1] voice channels or 10 multiplexed channels of 9600 baud data service modem inputs.

To further illustrate, if one of the six fibers in the cable were dedicated to purely digital telephone trunking, nearly 5,000 standard half-duplex voice channels (Bell-type 64 kb/s logarithmic companded voice) can be accommodated on one single-fiber.

3.4 Computer Simulation Model

An important tool used in the design of the 322 Mb/s digital fiber-optic link was the computer simulation model of the so-called "linear channel" of a repeater-to-repeater span. This model, shown in Figure 4, simulates the effects of the injection laser transmitter, the optical cable delay distortion or dispersion, the photodiode and amplifier, the noise filter and the equalizer on the received waveform prior to reshaping. The output of the computer model is a simulated eye pattern [2] which gives a measure of the quality of the channel. Figure 5a shows the eye diagram for a 2.8 km repeater span and no delay distortion equalization. The effect of a simple equalizer is illustrated in Figure 5b.

A photograph of the actual measured eye pattern over the 2.8 km optical link at 322 Mb/s is shown in Figure 6, confirming the predicted link performance using computer simulation.

The results of the computer simulation are coupled with the known noise characteristics of the receiver to predict the BER as a function of received optical power. Figure 7 gives this relationship for a 3 km repeater span both with and without delay distortion equalization. Further analysis shows that the degradation in BER performance caused by cable dispersion is slightly less than the noise penalty associated with equalization, so that the unequalized receiver is about 0.7 dB more sensitive than the

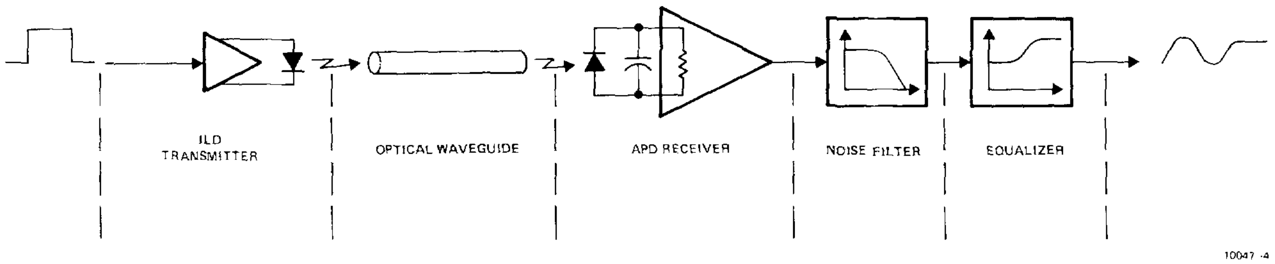

Figure 4. Linear Channel Waveform Simulation Model

[1] CVSD refers to Continuously Variable Slope Delta modulation, a companding method of digital voice modulation used to convert voice signals into serial NRZ digital data, and to reconvert that data into voice. These functions are currently available in single 14-pin CMOS integrated circuits, such as the Harris Semiconductor HC-55532 series.

[2] The eye pattern is an oscilloscope display used as a qualitative indication of the performance of a digital PCM system. The degree of "eye opening" enables one to tell at a glance the effects of bandwidth limiting and noise accumulation in the system. In general, the wider the eye opening, the lower the probability that the receiving equipment will make errors in reading the binary digits of the PCM bit stream.

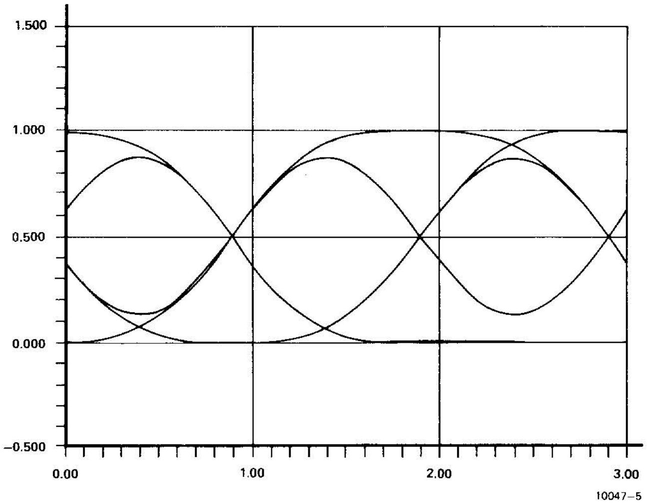

Figure 5a. Simulated Eye Diagram for Unequalized 2.8 km, 322 Mb/s Repeater Span

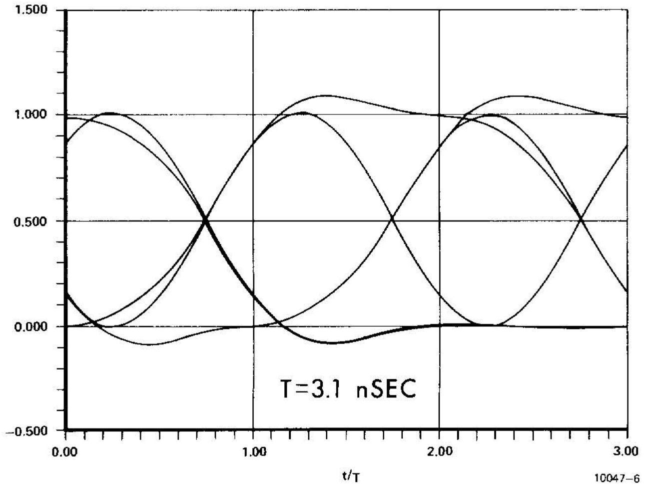

Figure 5b. Simulated Eye Diagram for Equalized 2.8 km, 322 Mb/s Repeater Span

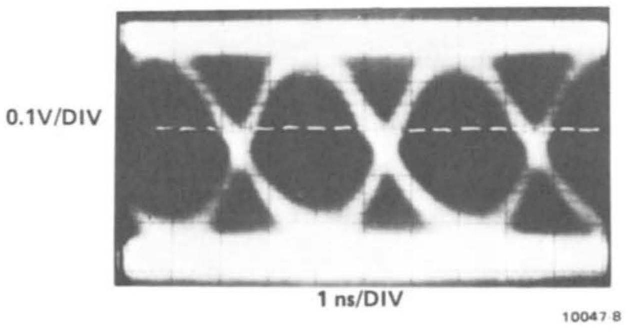

Figure 6. Measured Eye Diagram for Unequalized 2.8 km, 322 Mb/s Repeater Span

equalized receiver. Therefore equalization of the repeater link in this case offered no advantage whatever in performance, and the link contains no equalization circuitry.

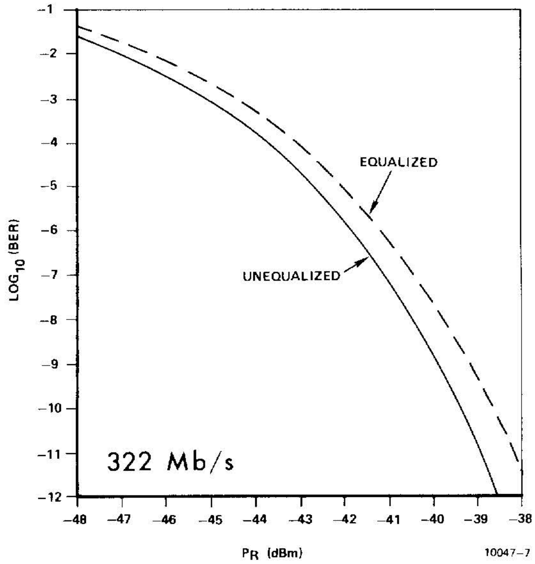

Figure 7. Bit-Error Rate Versus Average Received Optical Power

4.0 AUTOMATIC FAULT DIAGNOSTICS

One of the major objectives in the design of this system was to directly address some of the most challenging operational and maintenance concerns of the CATV industry:

- How does the CATV system operator determine the location and nature of a system failure?
- Is it possible to provide an "early warning" system to the CATV operator, providing in advance, the location, nature and rate of degradation of a system link component?
- Can the means be provided by which both the long- and short-term system performance parameters can be monitored to provide trend data?

Several technical approaches were considered to meet these challenging requirements, ranging from simple manual test sets to computer-controlled automatic test sequencers. The selected approach was incorporated on a medium-complexity, yet cost-effective digital on-line performance monitor called the Link Test and Maintenance Unit (LTMU), which is included as part of the total system equipment configuration.

The LTMU provides meaningful on-line data to the system operator about every important parameter in the system, including bit-error rate, repeater quality and condition and remote temperature conditions.

In comparison to previous CATV system performance monitors, the LTMU represents a quantum jump in the level of system fault diagnostic equipment. Yet in comparison to the technology of the fiber-optic trunking system to be monitored, the LTMU represents a reasoned trade-off between test sophistication and the requirement for a practical tool for system operator personnel.

4.1 Continuous Monitoring

The LTMU continuously monitors the bit-error rate of the digital bit stream at the receiver terminal. An automatic audible alarm is intitiated at the hub terminal location if the system BER exceeds a preset threshold.

In addition to BER monitoring, the LTMU can "call up" any transmitter or receiver module in any fiber-optic repeater unit anywhere in the system, and ask for qualitative status and performance information. This process of digital "interrogation-and-response" to and from the LTMU to other remote system components is the key to rapid fault location and an early warning system of degraded performance.

A transponder module located in every repeater unit enables the LTMU and repeater subassemblies to digitally communicate via unique digital code addresses to each subassembly. Each unit so addressed replies qualitatively as to the condition of the laser transmitter or the photodiode receiver. These data are visually displayed along with BER performance on the LTMU's digital panel readout. The system operator technician simply records these values periodically in a daily log. Thus, any data trends toward degradation will become apparent as variations from given tolerances, and corrective action can be taken before a catastrophic failure occurs and the link goes down. Further, a repair technician can identify from the LTMU the exact repeater, subassembly and module to be replaced before he leaves the shop.

The cost benefits to the system operator in fault location time, troubleshooting, system reliability and customer service complaints are apparent.

5.0 CONCLUSION

This paper has presented a report on the first major CATV installation of fiber optics trunking using digital television transmission. Fiber optics CATV transmission offers both a challenge and a promise: A challenge for the CATV community to adapt and cope with a rapid technological changeover, and the promise of economically providing extended broadband services to outlying or marginally populated market areas not previously considered within reach.

Acknowledgements

The authors wish to acknowledge valuable technical discussions and contributions to this paper by Paul Casper and Ray McDevitt of Harris ESD, Nick Hamilton-Piercy and Ed Jarmain of Cablesystems Engineering, and Joe Proctor of Canada Wire and Cable, Ltd. of Toronto.

BASIC ACOUSTICS FOR THE CABLE TELEVISION STUDIO

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This tutorial paper shows how to calculate the optimum reverberation time for a studio, based on its volume and whether it will be used for voice or music. Also given is the calculation of the actual reverberation time, based on the studio's volume, surface area, surface materials and contents. Using three typical local origination size studios as examples, methods for improving reverberation time are given.

Once a local origination studio has been constructed to minimize the transmission of external sounds through its walls, doors and windows, consideration must be given to the acoustical treatments necessary to control the reflections of sounds within the studio. If reflections are not sufficiently attenuated, the studio will have an unpleasant "hollow" sound, and in extreme cases, intelligibility will suffer. On the other hand, too much attenuation will give the studio a "flat" sound, which can be psychologically annoying to performers. A measure of this characteristic is reverberation time, with the symbol t_{60}. Reverberation time is defined as the time required for a sound's amplitude to decrease 60 dB.

The optimum reverberation for a broadcast studio being used for speech is given approximately by:

$$t_{60} = 0.3 \log V - 0.65 \qquad (1)$$

V is the studio volume in cubic feet, and t_{60} is in seconds. For a studio used for music, a reverberation time 250 milliseconds longer than this may be used.

To calculate the actual reverberation time in a studio, the equation is:

$$t_{60} = \frac{0.049\ V}{-2.3\ S \log (1-\alpha)} \qquad (2)$$

S is the total wall, ceiling and floor surface area in square feet and α is the average sound absorption coefficient (or acoustic absorptivity) of these areas. Figure 1 gives the absorption coefficients for a number of typical wall, ceiling and floor surfaces.

FIGURE 1

APPROXIMATE ACOUSTIC ABSORPTION COEFFICIENTS*

WALLS	
PAINTED BRICK WALL	.02
PLASTER	.03
UNPAINTED BRICK WALL	.04
PLATE GLASS	.06
WOOD PANELING	.07
GYPSUM BOARD ON 2 X 4 STUDS ON 16" CENTERS	.11
3/8" PLYWOOD	.16
COARSE CONCRETE BLOCK	.34
HEAVY DRAPED FABRIC	.46
FLOORS	
CONCRETE	.02
WOOD	.04
LINOLEUM ON CONCRETE	.06
UNLINED CARPET	.30
CARPET WITH PAD	.40
ACOUSTICAL TILES CEMENTED TO WALLS OR CEILING**	
1/2"	.55
5/8"	.60
3/4"	.70
1"	.75

* BASED ON MEASUREMENTS BY THE ACOUSTICAL MATERIALS ASSOCIATION LABORATORY.

** EXACT COEFFICIENTS FOR A PARTICULAR PRODUCT AND MOUNTING METHOD MAY BE OBTAINED FROM THE MANUFACTURER.

Let's see how these equations can be used to calculate the acoustic requirements in a 12' wide, 18' long and 9' high studio. Its volume is (12)(18)(9)= 1944 cubic feet, and its wall, ceiling and floor surface area is (2)(12)(18) + (2)(12)(9) + (2)(18)(9) = 792 square feet. From Equation (1), the optimum reverberation time is:

$$t_{60} = 0.3 \log 1944 - 0.65 = .337 \text{ seconds}$$

Rearranging Equation (2) gives

$$\alpha = 1 - 10^{\left(\frac{-0.0213\,V}{S\,t_{60}}\right)} \qquad (3)$$

By substituting the t_{60} calculated above and the studio's volume and floor, ceiling and wall surface area into the equation gives a required average coefficient of absorption of $\alpha = .30$.

There are, of course, a number of ways by which this value could be achieved. But let's assume a concrete floor, 1/2" acoustical tiles on the ceiling and gypsum board walls. The present average coefficient of absorption can now be found by:

$$\alpha = \frac{\Sigma S_i \alpha_i}{S} \qquad (4)$$

$$\alpha = \frac{(12)(18)(.55)+(12)(18)(.02)+(60)(9)(.11)}{792} \qquad (5)$$

$$= .23$$

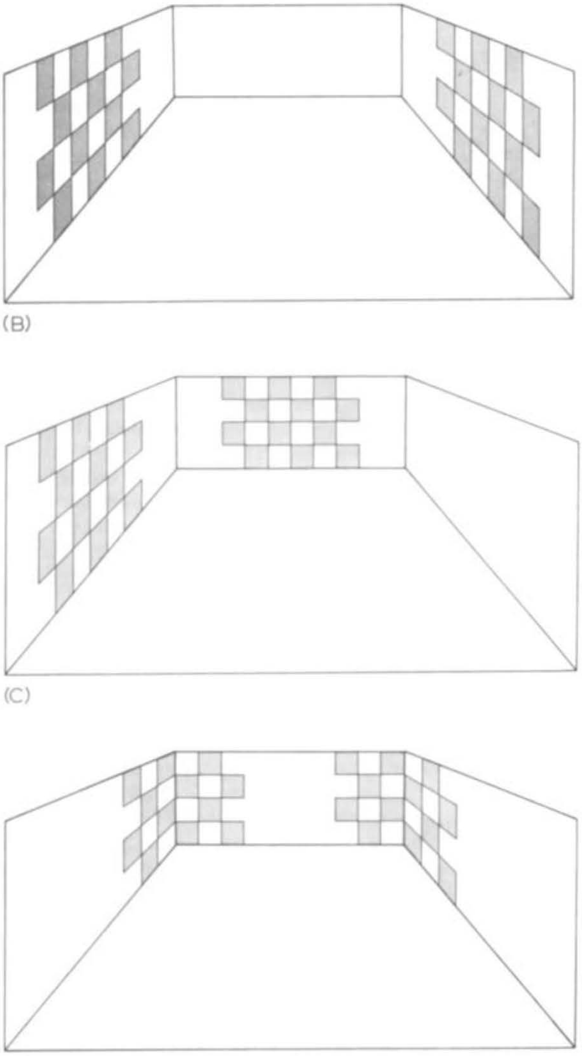
One way by which the average acoustical absorptivity could be increased from .23 to .30 would be by applying 1/2" acoustical tiles to an area, x, of the wall surface. Equation (5) would then become:

$$.30 = .155 + \frac{(540-x)(.11)+(x)(.55)}{792}$$

or:

$$x = 125.2 \text{ square feet}$$

Some rules of thumb that are helpful in distributing this 125 square feet of acoustical material most efficiently are illustrated in Figure 2.

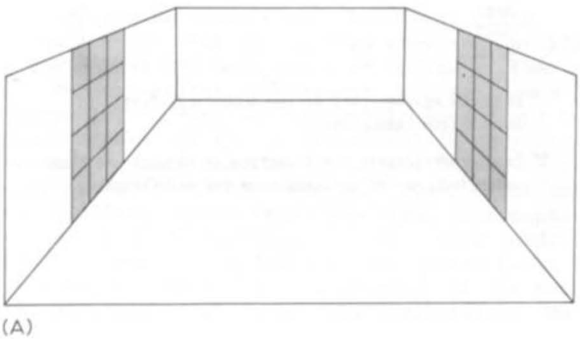


(B)

(C)

(D)

TIVE AB-SORPTIVE MATERIAL. DRAWING (B) REPRESENTS AN INCREASE IN EFFECTIVENESS OVER (A) BECAUSE THE MATERIAL HAS BEEN SPREAD OUT IN A CHECKERBOARD PATTERN OVER A LARGER WALL AREA. FURTHER IMPROVEMENT IS OBTAINED IN (C) WHEN THE MATERIAL IS PLACED ON ADJACENT, RATHER THAN OPPOSITE WALLS. IN (D) STILL ANOTHER IMPROVEMENT IS EFFECTED WHEN THE MATERIAL IS PLACED IN THE CORNERS, RATHER THAN ON THE CENTER, OF THE WALL SURFACES.



(A)

Let's look at a second example of an 8' long, 8' wide and 9' high announce booth with the ceiling and 50% of the wall area covered with 1/2" acoustical tiles and with a floor consisting of linoleum on concrete. The questions to be answered are: 1. What is the booth's reverberation time? 2. How much will the reverberation time be shortened by placing one person, a wooden chair and a small table in the booth? 3. How does this reverberation time compare with the recommended optimum?

The volume of the booth is (8)(8)(9) = 576 cubic feet, and its floor, wall and ceiling area is (2)(8)(8) + (32)(9) = 416 square feet. From Equation (4) and Figure 1:

$$\alpha = \frac{\Sigma S_i \alpha_i}{S}$$

$$= \frac{(64)(.55)+(64)(.06)+(144)(.55)+(144)(.11)}{416}$$

$$= .32$$

From Equation (2), the booth's reverberation time is:

$$t_{60} = \frac{0.049\ V}{-2.3 \times \log\ (1-\alpha)}$$

$$= \frac{(0.049)\ (576)}{(-2.3)(416)\ \log\ (1-.32)}$$

$$= \underline{.174\ \text{seconds}}$$

The effect which people and furnishings will have on reverberation time can be approximated by:

$$t_{60}\ (\text{furnished and occupied}) = \frac{S\alpha}{S\alpha + a}\ t_{60}\ (\text{empty}) \qquad (6)$$

Where "a" is the acoustical absorption, in sabins, of the furnishings and occupants. The absorption of the person, chair and table is, from Figure 3, 4+1+1 = 6 sabins.

FIGURE 3

APPROXIMATE OCCUPANT AND FURNISHING ABSORPTIONS IN SABINS

SMALL TABLE	.3
WOOD CHAIR	.3
DESK	1.0
PERSON	4.0

From Equation (6):

$$t_{60}\ (\text{furnished and occupied}) = \frac{416(.32)}{416(.32) + 6}\ (.174)$$

$$= .168 \simeq \underline{.17\ \text{seconds}}$$

From Equation (1), the recommended reverberation time is:

$$t_{60} = 0.3 \log V - .65$$

$$= 0.3 \log 576 - .65$$

$$= \underline{.18\ \text{seconds}}$$

This is certainly close enough to the calculated .17 seconds, especially considering the tolerances on the acoustical absorptions and absorption coefficients we have used (about $\pm$ 20%).

Figure 4 shows the reverberation time versus average acoustical absorption coefficient for three typical local origination studios. The optimum reverberation time for each studio is also shown; it can be seen that most local origination studios will require an average acoustic absorption coefficient close to .3.

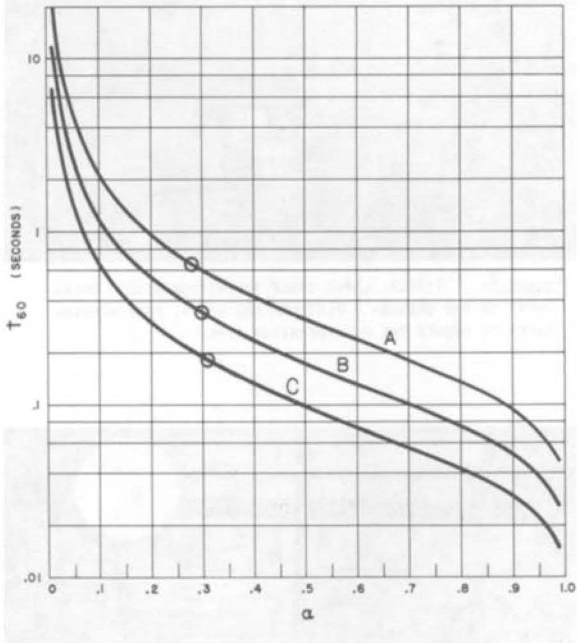


FIGURE 4: GRAPH SHOWING RELATION BETWEEN REVERBERATION TIME, T_{60}, AND THE AVERAGE ABSORPTION COEFFICIENT, α, FOR A LARGE 30 x 40 x 18 LOCAL ORIGINATION STUDIO (CURVE A), A SMALL 12 x 18 x 9 STUDIO (CURVE B) AND AN 8 x 8 x 9 ANNOUNCE BOOTH (CURVE C). THE CIRCLED POINTS ON THE GRAPH SHOW THE OPTIMUM REVERBERATION TIMES FOR THESE STUDIOS WHEN THEY ARE USED FOR SPEAKING; FOR MUSIC, REVERBERATION TIMES APPROXIMATELY 250 MILLISECONDS LONGER WOULD BE OPTIMUM.

Although these values and equations provide useful guidelines for determining the required acoustical treatment for a local origination studio, to do a rigorous acoustical analysis of a studio would require considering a number of additional factors beyond the scope of this paper, including the frequency spectrum of the sounds being created, the humidity in the room and the placement of objects and furnishings within the room.

Try these calculations on your studio. Maybe, with just a minor amount of acoustical treatment to the studio, your performers won't sound like they're inside a barrel any more.

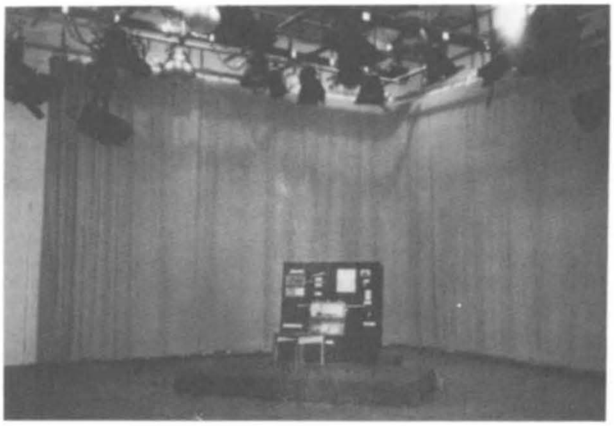


FIGURE 5: TYPICAL LARGE CABLE TELEVISION STUDIO USING CARPET ON THE SPEAKER'S PLATFORM AND HEAVY, FREE-HANGING DRAPES TO REDUCE THE REVERBERATION TIME.

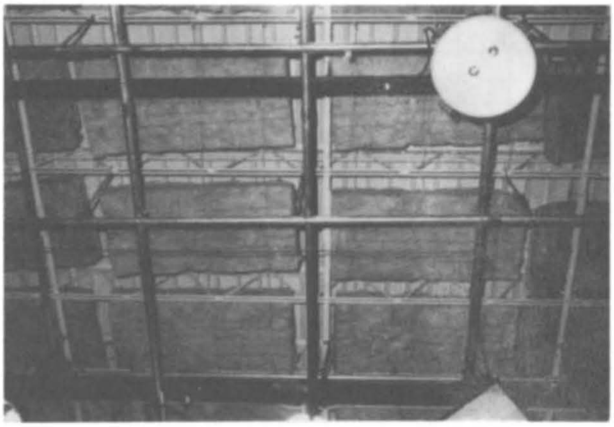


FIGURE 6: FIBER GLASS BATTS, 2' x 4' x 6", PLACED ABOVE LIGHTING BATTENS TO REDUCE REVERBERATION TIME.

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CABLE TELEVISION INSPECTIONS BY FOB FIELD ENGINEERS

Presented by

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ABSTRACT

Engineers with the Federal Communications Commission's Field Operations Bureau have responsibility for inspecting cable television systems. This paper discusses the considerations of selecting a system for inspection, the organization and responsibilities of FCC field units, some of the general technical procedures followed, recent inspection findings and inspection follow-up. Also, the cable operator's responsibilities in assisting with the inspection are outlined.

INTRODUCTION

The FCC Field Operations Bureau (FOB) is responsible for Commission engineering activities performed in the field, including enforcement, interference suppression and communications user liaison. Working with CATV systems is nothing new to the bureau. Our first experience was obtained in the fifties in radiation leakage complaints involving TV interference to nonsubscribers. At that time, restrictions were specified in Part 15 of the FCC Rules and Regulations (Radio Frequency Devices).

After the adoption of signal quality specifications, Part 74 and later Part 76 of the Rules and Regulations, our FM/TV Enforcement Units routinely began making complete system performance measurements. Other field facilities began random inspections for a one-year period during 1975, gathering data from performance measurements conducted by system operators and also began and have continued, making other inspections for cause. More recently, several select field facilities have concluded a survey to determine the extent of cable television leakage radiation. The findings of this survey will be used to assist in analyzing cable TV's potential interference to aircraft radio systems.

FOB ORGANIZATION

The Field Operations Bureau is composed of six regions, consisting of 31 district and limited offices, 13 monitoring stations and 5 special enforcement facilities, each staffed with electronic engineers and technicians. The regional boundaries and location of individual facilities are shown on Illustration 1.
There are also four FM/TV/CATV enforcement units that specialize in technical analysis of FM broadcast, television broadcast, and cable television systems. The home bases of these units are as follows:

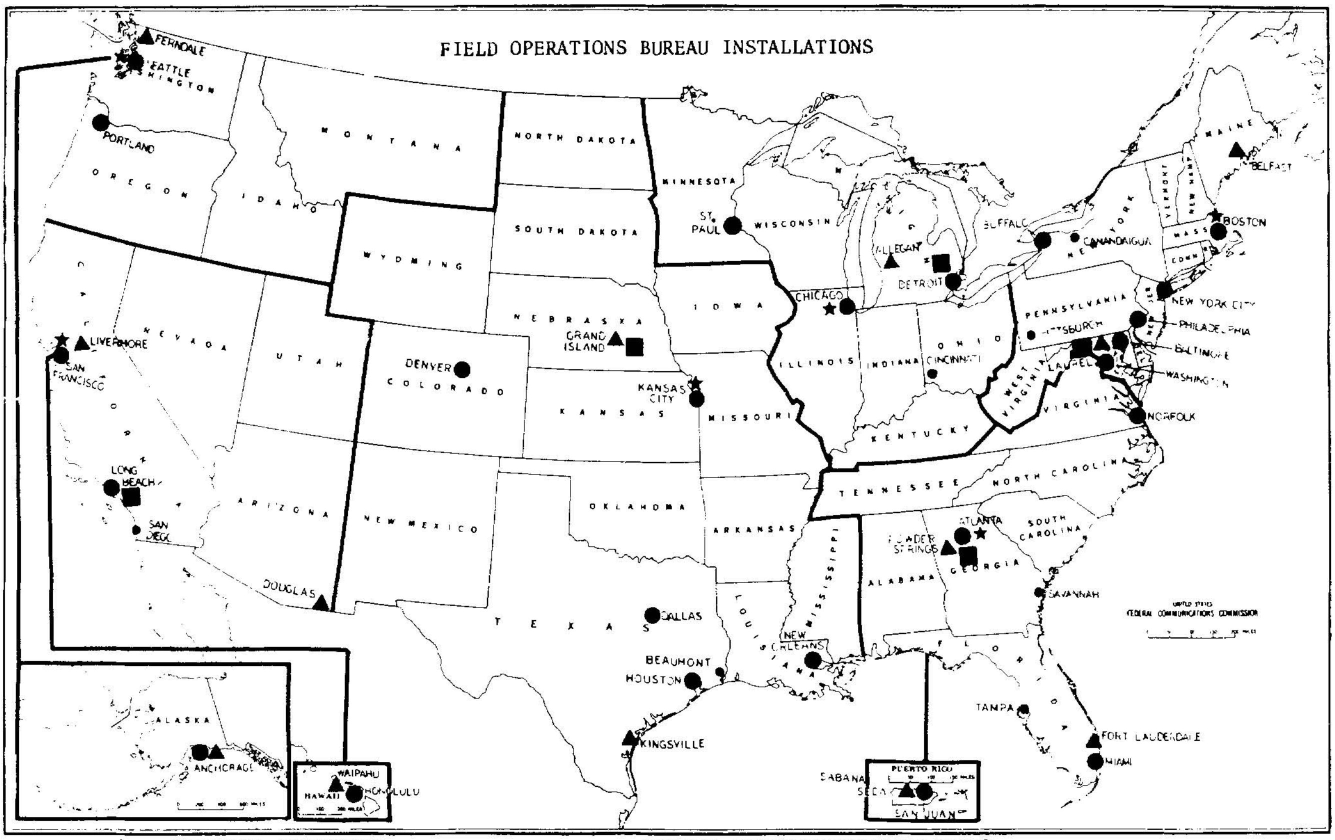
Eastern FM/TV/CATV Unit	- Norfolk District Office
Southern FM/TV/CATV Unit	- Powder Springs, GA Monitoring Station
Central FM/TV/CATV Unit	- Kansas City District Office
Western FM/TV/CATV Unit	- San Francisco District Office

Each of the FM/TV/CATV units is approximately a $100,000.00 package consisting of a 2.5-ton truck, sophisticated test equipment and trained engineer specialists. See Illustrations 2 and 3.

An average FOB inspector begins his career with the Commission soon after receiving a BS degree in Electrical Engineering. Others are hired after working in related fields in private industry. The first assignment is a six-month comprehensive training course that provides a broad overview of the bureau's responsibilities and methods of accomplishing those responsibilities. A duty station is next assigned and career development continues through on-the-job training until journeyman level is obtained, usually in three years. The inspector is a generalist working with marine, land mobile, broadcast, aviation, citizens, cable television and other services. After obtaining journeyman status, a speciality such as an FM/TV/CATV unit might be selected or a senior engineer classification obtained.

CABLE SYSTEMS SELECTED FOR INSPECTION

The bureau has limited resources that can be devoted to cable television enforcement. Therefore, most cable systems selected for field inspection are selected for some specific cause such as the following:



★ – REGIONAL DIRECTORS
● – FIELD OFFICES
▲ – MONITORING STATIONS
■ – SPECIAL ENFORCEMENT FACILITIES
• – LIMITED OFFICES

Illustration 1. Map Showing Location of FOB Field Installations

Illustration 2. Exterior View of FM/TV/CATV Unit

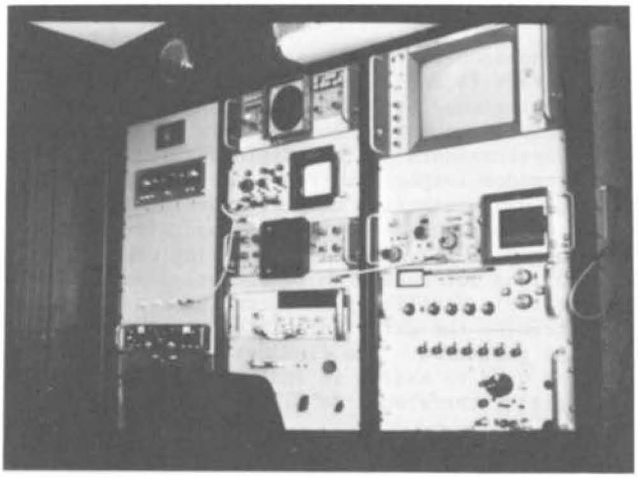


Illustration 3. Test Equipment Rack in FM/TV/CATV Unit

1) Subscriber complaints that are not resolved by the cable operator. 1/

2) Signal quality controversies between cable operators and television station operators where conflicting technical reports have been filed with the Commission.

3) Gathering background or evidentiary material for use by another bureau or office.

4) Although the majority of cable television inspections performed by FOB fall into one of the above categories, a few are based on random selection.

It might be well to note that FOB should not be thought of as a substitute for a private consultant. We provide independent findings for enforcement and to resolve conflicts on which a Commission decision depends but we do not provide findings in lieu of normally expected submissions from a cable operator.

CONDUCTING THE INSPECTION

Since inspections are usually for "cause" the tests and measurements performed vary according to the particulars of the individual case. A subscriber complaint of poor picture quality that goes unresolved usually requires conducting the complete technical performance measurements specified in Section 76.605 of the Rules. Additionally, using a television receiver of known characteristics connected to the subscriber tap the picture quality of each received channel is subjectively evaluated and rated according to modified TASO 2/ procedures. Remember the Rules require that "the signal shall be carried without material degradation in quality (within the limitations imposed by the technical state of the art)." 3/ We feel this TASO evaluation provides the best determination of "material degradation."

Occasionally, a cable operator and a television station operator become deadlocked in fixing blame for degraded signals at cable subscriber taps. Here again a complete set of cable technical performance measurements as outlined in Section 76.605 of the Rules are conducted and the television station's off-the-air signal receives a detailed waveform analysis to determine compliance with Part 73 of the Rules. Clarity and picture fineness are measured by having the television station transmit a standard resolution test slide and then simply counting lines of horizontal resolution at various points along the signal path, i.e., television transmitter output, cable headend, and cable subscriber taps. Acceptable high quality television pictures should contain over 325 to 350 lines of horizontal resolution. Subjective TASO picture evaluations are also made at various points. 4/

Signal carriage disputes often center around a television station's field strength 5/ over a community or at a cable headend location. FOB determines the contour over a community by the spot sampling technique outlined in the TASO report. Using this method a rectangular grid is positioned on a city map with the number of intersections adjusted to equal three times the square root of the city population in thousands. Cluster measurements are then conducted at each intersection and the median value determines the signal grade. At the headend, the signal grade is determined by making measurements at five random locations within 100 feet of the cable system receiving antenna. For safety and convenience all measurements are made at ten feet and corrected to thirty feet.

The illustrations listed above are typical of FOB cable inspections. Every effort is made to conduct all relevant measurements and this may require that the FOB engineer spend from one-half day up to one week working at the cable system. The inspector is equipped with all necessary test instruments and independently performs most measurements. The cable operator is expected to cooperate, as needed, in supplying test taps, access to the headend, required records and details of the plant layout. Most systems find it convenient to assign a technician to accompany the inspector full-time but this is at the cable system's option.

RECENT INSPECTION FINDINGS

Recent inspections show that nearly all cable systems checked by FOB are in violation of one or more of the Commission's technical regula-

1/ Subscriber complaints are filed with the local engineer-in-charge or the cable bureau in Washington. First action on the complaint is a request to the cable operator to investigate, take corrective action if necessary, and report back.

2/ Ratings range from 1 (Excellent) to 6 (Unusable). See Engineering Aspects of Television Engineering, Report of the Television Allocations Study Organization (TASO) to the Federal Communications Commission, March 16, 1959.

3/ 47 CFR 76.55.

4/ This procedure is outlined in the Initial Decision released August 21, 1973, in Docket No. 19479, Meadville Master Antenna, Inc.

5/ Sharply defined field strength boundaries determine a stations Grade A and B contours.

Channel	Grade A (dBu)	Grade B (dBu)
2 - 6	68	47
7 - 13	71	56
14 - 83	74	64

See 47 CFR 73.683.

tions. 6/ In Table 1, the "frequently" and "occasionally" violated rules are listed. This may serve as an indication of where greater preventive attention might be warranted.

Table 1

Frequently Violated Rules

76.601(c)	- Yearly performance tests
76.605(a)(2)	- Visual carrier frequency tolerance
76.605(a)(4)	- Signal level at subscriber tap
76.605(a)(5)(i)	- Ratio of adjacent channel signals
76.605(a)(6)	- Ratio of aural to visual signals
76.605(a)(7)	- Low frequency hum
76.605(a)(8)	- In channel frequency response
76.605(a)(12)	- Radiation

Occasionally Violated Rules

76.307	- System available for inspection
76.55(a)(1)	- Material degradation
76.605(a)(3)	- Aural carrier frequency tolerance
76.605(a)(5)(ii)	- Ratio of nonadjacent channel signals
76.605(a)(9)	- System noise
76.605(a)(11)	- Terminal isolation

As part of the survey mentioned earlier, dealing with leakage radiation and possible adverse affects on aeronautical transmissions, FOB has just concluded tests on 65 cable plants. Eighty percent of the systems had one or more leaks of at least 50 mV/m at 10 feet. Seventeen percent of the leaks were above 350 mV/m at 10 feet and one leak measured 5600 mV/m at 10 feet. These findings indicate leakage radiation exists in seemingly significant quantities. A second phase to the study is being implemented to determine the actual affect on aircraft communication and navigation devices.

FOLLOW-UP ACTIONS

Rule violations that are noted during an inspection are brought to the cable operator's attention during a wrap-up session immediately following the completion of all measurements and later by written correspondence. A reply to the written correspondence is requested within 10 days indicating what corrective action is being taken to remedy the discrepancy. The inspecting engineer reviews the reply, provides comments as appropriate and forwards the complete inspection package to Washington headquarters.

6/ Admittedly, the sample is biased because of the selection process and the statement should not be applied to systems in general.

In Washington, FOB personnel review the inspection package for accuracy and to determine what further action, if any, appears warranted. If a violation remains uncorrected, evidence indicates repeated or flagrant violations, unusual problems are evident or special interest was previously expressed, the package is coordinated with cable bureau for follow-up.

On February 21, 1978, a bill was signed by the President amending the Communications Act of 1934, to, among other things, broaden Commission administrative forfeiture procedures to include cable television systems. Procedures for implementing this new authority are being developed at this time. The amendment provides for a maximum cable forfeiture of $2,000 per violation per day with a total penalty not to exceed $20,000. Under the new law, a violation has occurred when any person has:

> "A) willfully or repeatedly failed to comply substantially with the terms and conditions of any license, permit, certificate, or other instrument or authorization issued by the Commission;
>
> "B) willfully or repeatedly failed to comply with any of the provisions of this Act or of any rule, regulation, or order issued by the Commission under this Act or under any treaty, convention, or other agreement to which the United States is a party and which is binding upon the United States;
>
> "C) violated any provision of Section 317(c) or 509(a) of this Act; or
>
> "D) violated any provision of Section 1304, 1343, or 1464 of title 18, United States Code...."

Further, in determining the amount of such a forfeiture penalty, the Commission or its designee shall take into account the nature, circumstances, extent and gravity of the prohibited acts committed and, with respect to the violator, the degree of culpability, any history of prior offenses, ability to pay, and such other matters as justice may require.

This new legislation should provide great flexibility in administering the cable enforcement program. However, I would like to stress that good cable service is the goal and penalties against a cable operator should be thought of as a final method of achieving that goal. I would think the average cable operator will never be faced with a Commission penalty for technical problems.

One notable exception to the general policy procedures for implementing administrative action, is the authority delegated recently to local engineers in charge to require a cable system that causes harmful interference to radio communications involving the safety of life and protection of property to cease operations as necessary to eliminate the interference. 7/ The authority is used with discretion and only with substantiated safety and property protection interference problems. Every effort is made to minimize any social, economic or technical effects on the system and system subscribers. For example, it may only be necessary to remove one specific carrier frequency. Similarly, the system operator is expected to react in an urgent and responsible manner when he becomes aware of any harmful interference.

CONCLUSIONS

The Field Operations Bureau's cable television inspection program has been operational for several years. Principal goals of the program are complaint resolution, detection of rule violations and engineering data collection. Since very limited resources are available, the program concentrates on problem areas.

We hope that responsible cable operators will welcome a system inspection by FOB engineers. It is an excellent opportunity for exchanging ideas and isolating and resolving technical problems.

7/ 47 CFR 76.613

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CHANNEL RESPONSE MEASUREMENTS MADE EASY

Gerald L. Bahr
Chief Engineer

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By employing a tracking generator/receiver system, (such as an Avantek sweep system) and incorporating a local oscillator with a double-balanced mixer, you can develop a side band analyzer that greatly facilitates the requirement to measure and make adjustments to head-end equipment, including video modulators.

This technique allows the channel response measurement to be made in the presence of other carriers, thus negat- the requirement to turn the system head-end off while making these measurements. Using this technique, the head-end and system can be measured as one integral unit, thus, with the aid of a camera, providing proof of the channel response for the total system and eliminating the need to algebraically add two or more response measurements together.

INTRODUCTION

Anyone who has tried to comply with the FCC requirements of in-channel response measurements realizes that it is a tedious job, often times producing less than satisfactory results. Typically, the "proof" pictures are of poor quality and the correction of problems found can be a slow and cumbersome process.

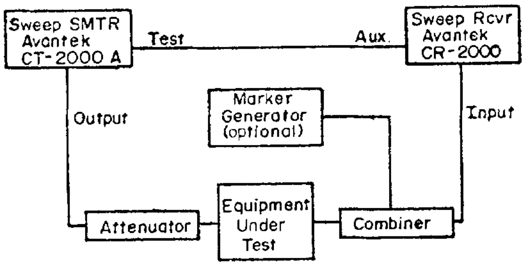
The problem has been in displaying a clean, steady and accurate response of a modulator, processor or strip amplifier with other carriers present. It is particularly difficult to prevent a modulator carrier from saturating the detector and/or masking the sideband information, either of which makes it impossible to achieve satisfactory results using the typical sweep generator/detector techniques.

The above problem can be overcome through the use of a sweep system using a tracking receiver. This paper will specifically explain the method using the Avantek CT/CR-2000A; however, the techniques will work equally well for earlier Avantek models or for tracking systems produced by other manufacturers.

TEST EQUIPMENT REQUIRED

1. Avantek CT/CR-2000A or equivalent.
2. Marker generator (RCA-WR99 or equivalent).
3. Double-balanced mixer (Anzac Model MHF-1 or equivalent.
4. VHF amplifier (may need two).
5. Video amplifier (may not need).
6. Assortment of pads, jumpers, etc.

SWEEPING ON-CHANNEL PROCESSORS

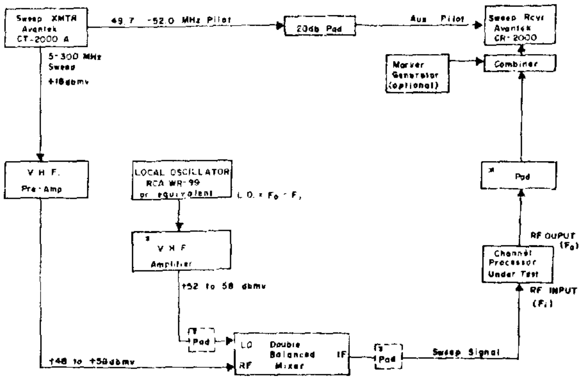


Set Up For Response Test
Of On-Channel Equipment

Figure 1

Figure 1 is the set up for sweeping on-channel equipment. This method is similar to the typical sweep generator/detector method and does not use the double-balanced mixer. The marker generator is used for marker reference only. For further details refer to the Avantek Manual, Section 12, page 30, under "Proof of Performance Measurements".

SWEEPING OFF-CHANNEL PROCESSORS



*as required

Off-Channel Processor Sweep
Test Set Up

Figure 2

Figure 2 is the set up for sweeping off-channel processors. Note that the marker generator is used as a local oscillator. The generator is set to the difference in the channel input frequency and channel output frequency. The products of the DBM are both the sum and difference of the LO and RF frequencies and this set up will provide the proper input sweep for any channel conversion.

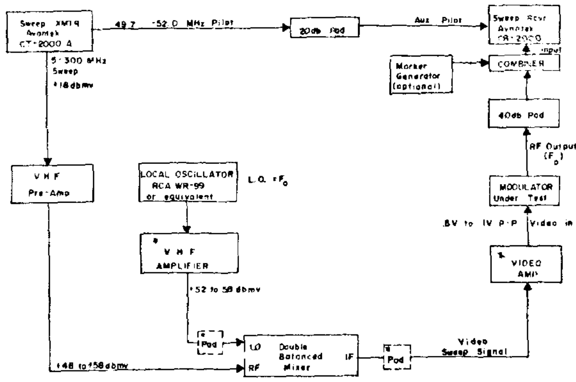
IF INPUT SWEEPING

An IF input sweep uses the above set up as Figure 2 with the LO generator set at 45.75 MHz above the output channel frequency.

SWEEPING MODULATORS

Figure 3 is the set up for sweeping modulators. Note that the generator is set to the same frequency as the output channel video carrier.

In Figures 2 and 3 the VHF amplifier, pads and/or the video amplifier marked with an asterisk may or may not be required, depending upon your individual equipment.



*as required

Modulator Sweep Test Set Up

Figure 3

DOUBLE-BALANCED MIXER CAUTIONS

A word of caution regarding the use of double-balanced mixers is in order at this point. The DBM is a useful and versatile tool, and, if used properly, it will provide excellent results. The first rule to remember is that the IF port must be terminated in a resistive load such as a pad, variable attenuator or an amplifier if the amplifier has a good input match well beyond the total bandwidth in question. Unless you know exactly what you are doing, do not terminate the IF port directly into a bandpass filter. If the IF port is terminated into a reactive load, the harmonic modulation products can vary as much as ±20 dB with the conversion loss varying as much as ±3 dB.

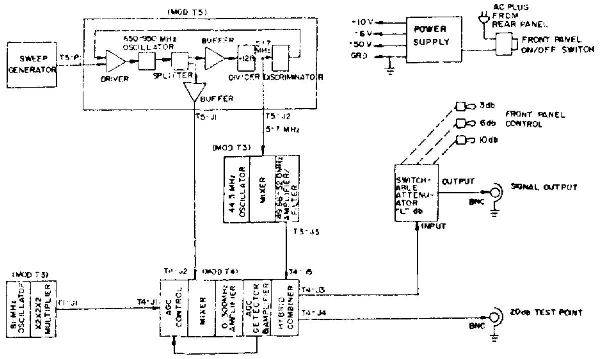
The LO port is the next most critical. The main caution here again is to use a resistive load. The RF port is not critical as the impedance that it sees.

For most DBMs used in CATV the local oscillator input level should be +52 to +58 dBmV.

A DBM with an impedance of 50 Ohms represents a return loss of 14 dB when used in a 75 Ohm test set up. If the above precautions are followed there should be no problems using a 50 OHm device.

AVANTEK SET UP

It is necessary to modify the Avantek transmitter to remove the 49 MHz to 52 MHz pilot from the sweep in order to prevent overloading the VHF amplifier and/or the double-balanced mixer.



Avantek Block Diagram

Figure 4

Refer to Figure 4 for the Avantek block diagram and make the following modifications:

1. Remove the jumper between T3-J3 (output of pilot amplifier/filter) and T4-J5 (input to hybrid combiner).
2. Disconnect the jumper at T4-J4 (one output of hybrid combiner) and reconnect at T3-J3 (output of pilot amplifier/filter).

This now sets the transmitter up so that only the pilot is available at the test point jack and only the sweep at the sweep signal jack.

MODULATOR SWEEP TEST PROCEDURE

The modulator sweep test procedure is typically the most difficult of the head-end units and for the sake of brevity will be the only one treated in detail in this paper.

Refer to Figure 3 and note that the sweep output of the Avantek transmitter is only +18 dBmV. This signal needs to be amplified approximately 30 to 40 dB. The higher the output of the amplifier the better, as long as the amplifier does not overload and the combined sweep and LO powers don't burn out the DBM (some DBMs can handle combined powers of 65 to 70 dBmV without burning out).

Feed this high level sweep signal into the RF port of the DBM. Then connect the local oscillator (RCA-WR99 or equivalent) to the LO port of the DBM. If either the RF sweep or the LO level is low into the DBM it may be necessary to install a video amplifier between the IF output of the DBM and the input to the modulator since 0.5 to 1.0 volt of video signal is necessary for proper modulation.

With the proper IF (video) signal level into the modulator, connect its output to the input of the Avantek receiver. Then connect the pilot tone from the Avantek transmitter (now located at the test point jack) to the auxiliary pilot input on the receiver.

The modulator is now set up for sweep testing. Note that is mav be necessary to pad the modulator output and/or the pilot tone to keep from overloading the Avantek receiver.

This test set up could be expanded to include the total cable system by inserting the Avantek transmitter pilot (at the proper level) into the trunk cable and taking the Avantek receiver out into the system.

If the head-end has a multi-channel AML transmitter with transmitter monitoring, the AML transmitter can be included in the test. However, since the AML can't transmit the 49-52 MHz pilot, the test cannot be run beyond the head-end.

To perform the sweep test, set the Avantek receiver controls as follows: video filter to normal; sweep rate to remote lock; video gain to 10 dB per centimeter; and sweep width to full. Then, with the transmitter in the local control mode, tune F_1 approximately 30 MHz below and F_2 approximately 30 MHz above the output video carrier frequency as indicated by their respective dials (these controls are internal pots on the Avantek transmitter models earlier than the 2000A). The video carrier should now be displayed on the receiver CRT with the base line being approximately two centimeters long and the video carrier near the center of the base line. Now tune the center frequency control so that the tuning marker is under the video carrier. Switch the sweep width to 1 MHz per division. The video carrier should now be displayed near the center of the CRT.

With the center frequency control move the video carrier two centimeters to the left of center and adjust F_1 and F_2 on the transmitter so that the base line just fills the full 10 centimeters of the CRT. Reduce the sweep rate on the transmitter to just above the flickering point, as viewed on the CRT. Now adjust the LO generator to the video carrier frequency. As the generator is tuned near the video carrier frequency, the response of the modulator will begin to rise up from the base line. Tune the LO generator for maximum level on the response as viewed on the CRT. The LO is now tuned to the video carrier frequency.

As the LO generator is tuned for maximum, it may be necessary to adjust the gain of the video amplifier (if used) and/or the video modulation control to prevent over-modulating the video modulator. It is best to adjust the modulation so that the sideband energy is approximately 6 dB below the video carrier.

As can be seen in the response photographs (Figures 5 through 7), the display can be quite revealing. Figure 5 shows considerable reaction in the video passband area caused by the sound trap. Although in the interest of video sharpness it is desirable to have a video bandwidth of 7 to 10 MHz, it can be a detriment in a CATV system if the upper sideband information is allowed to extend into the upper adjacent channel as indicated in the photograph. Keep in mind that the FCC channel response requirement is only from -0.5 MHz to +4 MHz with respect to the video carrier.

Figure 7 is the response of a channel processor. Although the video carrier is not present, a marker generator could be used (as shown in Figure 3) to show the location of the video and/or sound carriers if desired.

With the logarithmic display it is possible to see the rejection level of the vestigial sideband change 10 to 30 dB depending upon the proper set up of the equipment and the proper installation of modules and jumpers.

Depending upon the tuning of the Avantek receiver, the tuning marker may not be as prominent as the one in Figure 5.

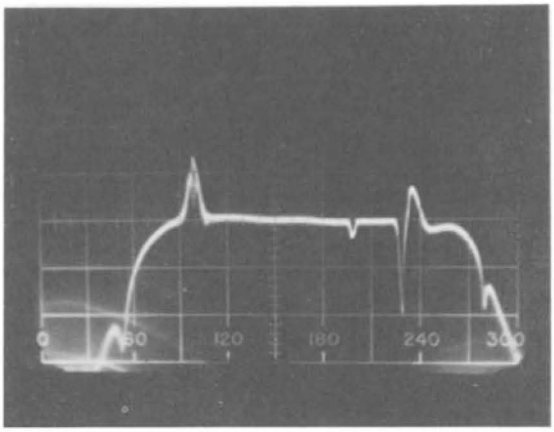


Figure 5

Vertical--10 dB/cm

Horizontal--1 MHz/cm

RCA CTM--10 modulator, bandpass filter and AML. Video carrier at the 100 MHz line. Tuning marker at the 200 MHz line. Sound trap at the 230 MHz line.

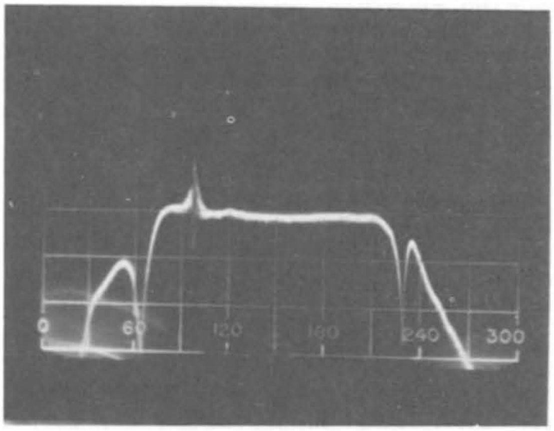


Figure 6

Vertical--10 dB/cm

Horizontal--1 MHz/cm

SA-6300--modulator, bandpass filter and AML video carrier at the 100 MHz line. Sound trap at the 230 MHz line.

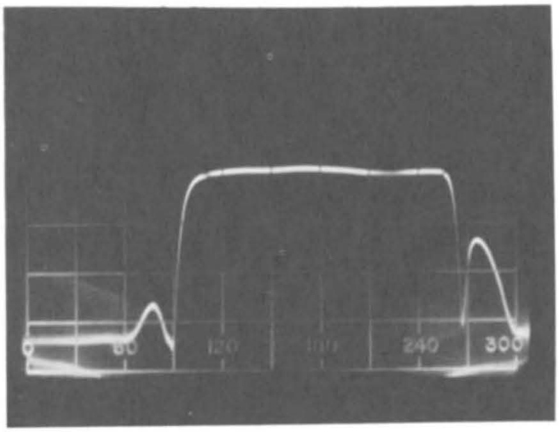


Figure 7

Vertical--10 dB/cm

Horizontal--1 MHz/cm

SA-6150--processor, bandpass filter and AML.

CONCLUSION

The sweep generator, with its tracking receiver, provides a means for fast and accurate in-channel response measurements. With two-way communications, two technicians can make the test from antenna terminals to the end of the system as one unit.

ACKNOWLEDGEMENTS

The double-balanced mixer that we used was the Anzac Model MHF-1, Stock No. MMN-6750. R.F. and I.F. response of 5 to 500 MHz with I.F. from D.C. to 500 MHz. Impedance 50 ohms.

Anzac Electronics, 39 Green Street, Waltham, Massachusetts 02154
Phone: (617) 899-1900

CO-CHANNEL PROTECTION LIMITATIONS OF THE CIRCULARLY POLARIZED (CP) ANTENNA-ARRAY

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ABSTRACT

Since the first experimental circularly polarized TV broadcast started in 1974 (Station WLS-TV, Channel 7, Chicago), the application of CP receiving antennas enjoyed growing interest among CATV engineers and system operators. This presentation is intended as an introduction to the reader on the concept of circular polarization, and will be followed by a review of methods to generate and receive CP electromagnetic waves. The discussion then focuses on the co-channel protection difficulties experienced with CP antenna-arrays, due to amplitude and phase distortions. Representative references are listed at the end of this paper, so the reader may conveniently interrupt this fast guided tour for more detailed studies in selected important topics.

DEFINITIONS

The electromagnetic field is composed of an electric (E) and magnetic (H) field vector. By definition, the polarization of the field is determined by the direction of the electric field vector. In case of linear polarization, such as a dipole above ground, the orientation of E coincides with the dipole. A horizontal dipole will emit horizontally polarized radiation. The vertical quarter-wave "whip" generates a vertically polarized field.

While in the case of linear polarization the direction of E remains always constant, (Fig. 1-a)

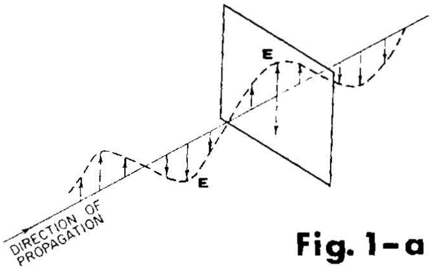

Fig. 1-a

in more general condition of circular polarization the direction of the electric field vector will change during each cycle, describing a circle (or ellipse) in the plane perpendicular to the direction of propagation. (Fig. 1-b).

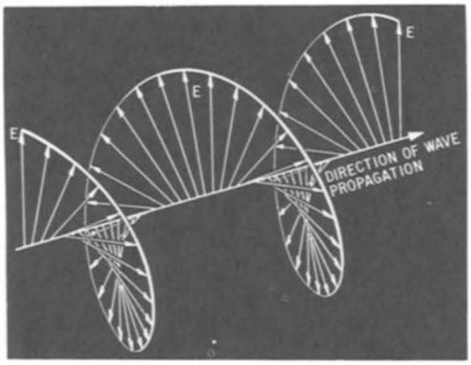

Fig. 1-b

If the rotation of the electric field vector is clockwise, as viewed in the direction of propagation, the polarization is defined as right-hand circular polarization. Similarly, a counter-clockwise rotation of the vector E will result in left-hand circular polarization. The FCC has ruled that the CP TV transmission in this country shall be right-hand circular.

Actually, circular polarization is very seldom circular. Most of the time the rotating electric vector will map an ellipse, with a certain minor-to-major axis ratio. (Fig. 2).

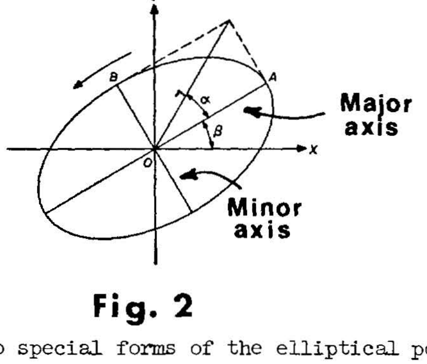

Fig. 2

The two special forms of the elliptical polarization are:

a. The case of linear polarization, when the minor-to-major axis ratio is zero, and the ellipticity approaches ∞ dB.

b. The case of circular polarization, when the minor-to major axis is one, and the ellipticity is ∅ dB.

GENERATION OF CIRCULAR POLARIZATION

Circular polarization can be generated by two crossed dipoles, feeding the dipoles with equal currents in "phase quadrature". (90° phase difference between the currents). A convenient way to achieve phase quadrature is to feed one of the dipoles through a cable which is $\lambda/4$ longer than the other feed line. (Fig. 3).

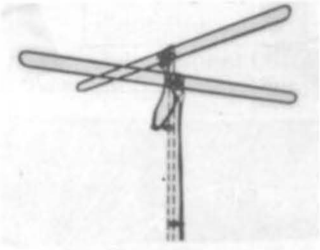

Fig. 3

An other approach requires the physical separation of the two crossed dipoles by $\lambda/4$. (Fig.4).

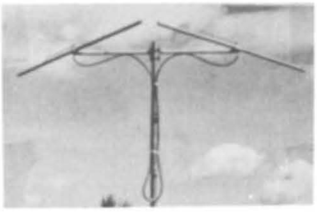

Fig. 4

The resulting field will again be circularly polarized.

A third method is the application of the helix. (Figure 5), radiating an unidirectional and circularly polarized beam.

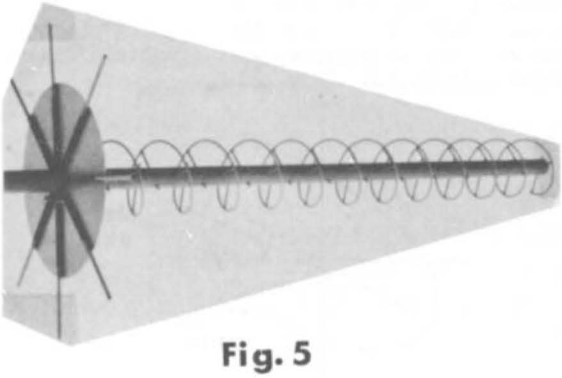

Fig. 5

Many other type of CP antennas, such as leaky wave, slotted line, open waveguide, etc. are frequently used in microwave communications or radar technology. Their concepts will not be discussed in this paper.

RECEPTION OF CIRCULAR POLARIZATION

Utilizing the principle of reciptrocity, the antennas shown for the generation of CP transmission could be also used for the reception of CP electromagnetic waves.

As a matter of fact, CP receiving antennas have been used for decades in CATV. Not to receive TV signals; but to receive FM signals. The popular FM turnstile antenna, Figure 3, operated in a planar mode (around the vertical axis), exhibits an omnidirectional horizontal radiation pattern, -3 dB gain in a single bay, and ∅ dB gain in a two-bay, vertically stacked configuration.

The CP receiving antenna of crossed Yagis or LP antennas, requiring a $\lambda/4$ phaseshift line between the horizontal and vertical bays, are operated in the axial mode. The phase lines, tuned to a single frequency, usually at the center of the frequency range of operation, provide the necessary phase quadrature only on that particular frequency. Consequently, on any other frequency the $\lambda/4$ line will introduce a moderate or considerable phase error. The calculation of gain, radiation pattern, beamwidth, or any other important performance parameter should use the same equations or principals as used in the development of single Yagis or LP antennas.

The helical antenna (helix) has been proven to be a practical and economical approach for producing circular polarization with excellent directivity, good gain, and a fairly wide impedance match. The gain of the helix, using the symbols of Figure 6, can be calculated by the following

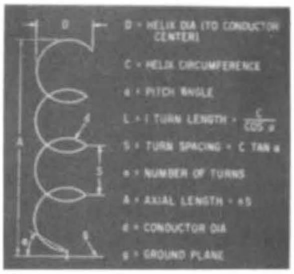

Fig. 6

equation:

$$G = 8.76 + 10 \log \left[\left(\frac{C}{\lambda}\right)^2 \cdot \frac{nS}{\lambda} \right]$$

Note, that the above formula is applicable only for the axial mode of operation. The obtained gain (in dB) is relative to a linearly polarized isotropic source, and valid for $\alpha = 12.5^\circ$ $g = 0.8\lambda$ and $d \cong 0.002\lambda$.

The desirable helical antenna dimensions are:

$$g = 0.85\lambda$$

$$A = 1.6\lambda$$

$$D = \frac{\lambda}{\pi}$$

For UHF and VHF high-band application the above dimensions are feasable. However, considering the dimensions of the Channel 3 helical antenna, where g=164", A=25'8" and D=61½", a back-mounted and suitable for orientation helical antenna becomes too large (unsafe) for installation on the average size CATV tower.

CP RECEIVING ANTENNA-ARRAYS

The technical requirements for CP receiving antenna-arrays are just as stringent as those for the CP TV transmitting antennas. First, a CP receiving antenna should receive the CP radiation as effectively as possible. In other words: the array should have a good impedance match, and polarization ratio. Secondly, the array should be rugged and reliable. Thirdly, the antenna-array should provide adequate protection against co-channel interference.

Arrays of CP antennas require special attention when feeding two or four bays from hybrid couplers (two-way or four-way splitters). The antennas must be paired in the proper sense (right-hand). If not, the array will operate in a linear mode of polarization, or worst yet, may work in a left-hand CP mode, and not receive the right-hand polarized TV transmission at all.

GHOST REDUCTION

The primary objective of the circularly polarized TV transmission is the elimination (reduction) of ghosting. Consider the case of a typical ground reflection problem, as illustrated in Figure 7.

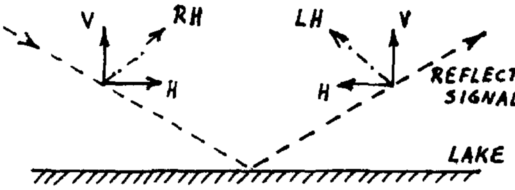

Fig. 7

A right-hand CP signal arrives from the left, suffering a total reflection from the surface of the lake. Note that the vertical component of the field has not changed in magnitude or in phase. However, the horizontal (H) component has suffered a 180° phase-shift. Consequently, the sense of polarization of the reflected wave changed to left hand, which cannot be received by the right-hand polarized CP receiving antenna. Circular polarization develops immunity against ghosting which is generated by off-the-air reflections.

Note: Should the TV transmission be polarized elliptically, which is actually an imperfect circular polarization, the cancellation of the reflection will be limited, depending on the axial ratio of the polarization.

CO-CHANNEL PROTECTION DIFFICULTIES

The reduction or elimination of ghosting is a highly desirable objective, achieved by the application of CP receiving antenna-arrays. However, the other paramount requirement, adequate co-channel protection, must not be sacrificed.

Co-channel interference protection is basically an antenna radiation pattern problem. What really counts is the horizontal (E) plane pattern of the receiving array, no matter whether the TV transmission was horizontally, vertically or circularly polarized.

The creation of deep and accurately placed (relative angle) null requires:

a. Absolute symmetry of the radiators
b. Freedom of reflections
c. Frequency independent phase-shift.

The radiators (antennas) of the array must provide equal amplitude signals to the combiners. For instance, a 30 dB deep null 40° off the main beam requires less than 0.35 dB amplitude difference between the two sides of the horizontally stacked two-bay array. It is suggested that antenna models, although identical, but produced at different times, should not be considered for array application.

Antenna-arrays are usually tested under "free space" conditions on the manufacturer's antenna test range. In the real world of CATV, diamond antenna-arrays are always mounted on tower legs, (36" to 40" face towers), and supported by long (resonating) crossarms. Quad-arrays of Yagis are generally antenna-gate mounted, which have long horizontal and vertical bars. Consequently, the antenna-arrays are exposed to reflections, generated by the cross-bars of the tower, the tower legs, crossarms, antenna-gates or booms, microwave reflectors, or any other CATV antenna-arrays, mounted unreasonably close to each other. The reflections cause amplitude and phase cancellations. The effects are unpredictable and difficult to calculate.

The third disruption of the optimum radiation pattern performance is caused by the $\lambda/4$ phase quadrature line, which is frequently dependent.

Numerical values of phase errors, as function of frequency (channel) of operation are given in Table 1.

	CHANNEL	PHASE ERROR
	2	20.0°
LOW-BAND LP ANTENNA	3	9.2°
PHASE-LINE TUNED TO CH 4	4	0.0°
	5	11.3°
	6	17.0°
	7	8.0°
	8	5.3°
HIGH-BAND LP ANTENNA	9	2.4°
PHASE-LINE TUNED TO CH 10	10	0.0°
	11	2.4°
	12	5.3°
	13	8.0°

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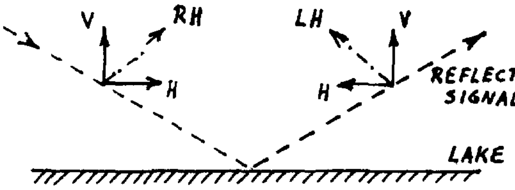

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	11	2.4°
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	13	8.0°

As an other example, consider the problem of determining the effect of varying amplitude and phase on the far-field radiation pattern of a four-bay, horizontally stacked antenna-array, designed for 10° and 21° co-channel angle protection. ($H=2.87\lambda$ and $H=1.4\lambda$).

The array factor; expressed for even number radiators:

$$E = \frac{1}{N}\left[\sum_{n=1}^{N} a_n (n-0.5)\psi\right]$$

where: N = number of radiators (antennas)

$$\psi = 2\pi\frac{d}{\lambda}\sin\Theta + \delta$$

Θ = the angle to the normal of the array-axis

a_n = the amplitude of the n-th radiator

δ = relative phase-shift between radiators

λ = wavelength

In a horizontally stacked antenna-array the relative phase-shift between adjacent elements must be:

$$\delta = -2\pi\frac{d}{\lambda}\sin\Theta_0$$

to ascertain the main beam of the radiation pattern normal to the array-axis (at Θ_0). Substituting δ into ψ

$$\psi = \frac{2\pi d}{\lambda}\left(\sin\Theta - \sin\Theta_0\right)$$

The calculated radiation pattern of the four-bay antenna-array, assuming 0° phase-shift and 0 dB amplitude variation is shown by the solid curve of Fig. 8.

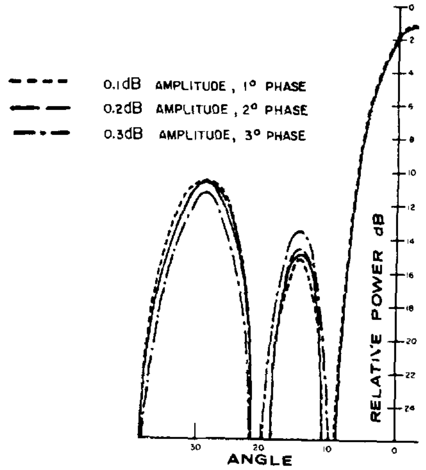

Fig. 8

The various dashed lines exhibit the distorted radiation patterns resulting from moderate phase and amplitude errors.

As illustrated, the deviations from the error-free condition generate no serious variations in the amplitude of the shoulders. However, the shifts in the radiation pattern nulls must not be neglected.

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DEVELOPMENTAL APPROACHES FOR AN EXISTING CABLE SYSTEM

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The paper will present, with the aid of audio-visuals, an analysis of the development of Manhattan Cable TV's programming effort, and the technical requirements needed to implement that effort.

A brief history of our unique system will be followed by a discussion of the new demands placed upon us, focusing particularlv on those demands placed upon the Transmission facility.

More frequent program switching to accomodate a heavier programming schedule, which includes Public Access, Leased Access, Municipal, Sports, and Special Event programs, plus promotional material, graphic interludes between these programs, and commercial inserts, will be required over 10 channels. In addition, more system-wide signal routing and switching capability is required to accomodate a growing number of remote sources that wich to feed live programming over the Cable system.

In conclusion, we will discuss the ways that each of our growth problems are being dealt with within our 10 year system. This includes partial automation, portableinfrared links, and signal processing equipment.

The subject of this report is the parallel evolution of programming concepts and hardware implementations at Manhattan Cable TV. This represents one area of development out of several currently going on at our cable system.

The initial concern of Manhattan Cable TV's efforts in New York City was to deliver better reception than over the air television, with little or no emphasis on originating programming. However, the franchise agreement stipulates that channels must be allocated for Public and Municiple access. The company set up a transmission facility in its business offices on 23rd Street, downstream from the headend. The purpose of this facility was to play tapes submitted by Manhattan's citizens for non-commercial Public Access cablecasting on a first come first served basis. The initial equipment was minimal, consisting of a few Sony ½" decks to accomodate the porta-pak material we were receiving. A small black and white studio was established with support from Manhattan Cable TV in a building next door. The studio, owned and operated by an independent non-profit organization, enabled producers to feed live programming and make studio recordings. There were some channel interconnects set up for Public Access between Manhattan Cable TV and Teleprompter Manhattan Cable TV in upper Manhattan, so that producers desiring to do so, could reach the entire borough. This interconnect is an RF switching system at the headend at 59th Street, controlled remotely by the Transmission room at 23rd Street.

This initial effort was met with enthusiasm and success. The amount of programming material began to grow, and many individuals turned their attention, full or part time, to being Access producers. Most turned out regularly scheduled series programs, and many of these producers are still with Manhattan Cable TV today. Soon, this escalation in programming began to define itself into specialized categories. A variety of ethnic programming appeared. Ethnic programming is economically feasible in New York City because of its many diverse ethnic communities.

On the Municipal side, one of Manhattan's Community Boards, Community Board 8, began to produce a monthly series based on their meetings. Manhattan's two city Councilmen-At-Large also started a regular series. Both of these programs were designed to increase participation in and awareness of local government.

Some Access producers, who had been particulary dilligent about their programs, wanted to see if their shows were commercially viable. Manhattan Cable TV tried, with its producers, to explore the commercial potential of the system. For a nominal fee, the company leased time to those producers on a commercially designated access channel. In turn the producers were able to sell advertising on their programs. Because of the increased credibility of Access, Municiple, and Leased programs, image quality and audio quality became more critical. Manhattan Cable TV responded to this need by the construction of its present transmission room and by participating in the construction of a second studio, origionally called Automation House and now called the Center for Non-Broadcast Television.

The new transmission room was built in a larger area, which gave us more flexibility. We expanded to twelve decks, six ½" and six 3/4". Three time base correctors were added to stabilize many of the tapes played on the system. Our new verticle interval switcher gave us a single memory capacity, which allowed us to start the programs on our channels at the same time. We also had the ability to switch the Center for Non-Broadcast Television studio, located on East 68th Street, onto the cable system, with the same RF switching system that allows Teleprompter Cable programs to be placed on our system.

The construction of the transmission facility, and in part, the 68th Street studio, was to accomodate the programs on the Public Access channels C and D, the Leased Access channel J, the municipal channel L (for which the Center for Non-Broadcast Television studio was mainly set up), and some alphamumeric channels. However, there have been considerable programming advances since the time of this last reconstruction which put demands on the room to the limit of what it was originally designed to handle.

Crucial to this development has been the introduction of low cost techniques for instant remote location programming from anywhere in Manhattan Cable TV's franchise area. Two artists working in the field of experimental television were the first to exercise this remote capability and did so on the Public Access channels. One artist desired to cablecast a real time mixture of two live sources and one tape source originating from the Whitney Museum of American Art on Madison Avenue and the Center for Non-Broadcast Television on East 68th Street. The signal from the Whitney Museum had to be delivered to the 68th Street studio to be mixed and from there we could switch the signal on the system via RF switching at the headend. Our problem was to bring the signal from Madison Ave. to East 68th Street. At the roof of the Whitney Museum we placed an infrared transmitter and beamed the signal to the Westbury Hotel on Madison Avenue between 70th and 69th Streets. From there, the signal was transferred to another infrared transmitter and sent to the studio. Infrared links do not have a considerably long over the air transmission range, but they are adequate enough to deliver a signal to the nearest cable drop somewhere in the city. In addition, the infrared links are not under FCC jurisdiction and are available at fairly low cost.

The second use of these links was part of a more involved project that was, in effect, a two way satellite hookup between New York and California. This was also a project produced for Public Access. A truck with a microwave dish was set up on the outskirts of lower Manhattan in a land fill region. The dish picked up the satellite signal from California and then relayed it from the landfill region to the cable system. The infrared link, had to send its signal around a corner to the nearest Cable drop. Adjacent to the cable drop , Manhattan Cable TV had a truck with an infrared receiver, picking up the signal and modulating it on the system.

In our earlier development , we saw how a programming concept such as Public Access and Public Leased Access led to our investment in more hardware; now our hardware was showing us the limits we can carry our software concepts to. These experiments with handling remote feeds has given us incentive and training for handling our own remote feeds to bring in advertising dollars. Manhattan Cable TV's first major remote was live coverage of the New York City Marathon on which we sold advertising. We also have remote feeds from Madison Square Garden and Nassau Coliseum feeding sports programs to the Transmission room where commercials are inserted and transmitted on the system. Our involvement with selling time during the sports programs required us to program two more channels.

With advertising and promotional material our tape load has increased considerably over the past year. We are now in the process of again rethinking our transmission facility. Full automation for switching is now needed. This proposed system will pre-roll our decks and send their signals to the appropriate channels. In addition it will mix audio, saving the operator the problem of scrambling to check the pots on 10 channels of audio. Of course having an automated switcher that will switch some 25 3/4" helical decks onto the available TBC presents its own particular problem. We have to route back advance vertical sync from the TBC to the deck we are using and also 358 feedback if we wish to go direct color for maximum picture quality. We are currently preparing a rebuild of this nature.

Our experience running transmission from early Public Access programming to our present situation outlines a logical parallel growth in equipment investment and programming plans. An idea came first, then some hardware. With the hardware, we were able to go beyond the original idea. This would lead to other programming ideas and then more equipment to handle these ideas properly. This process will eventually level off when our technical operation can accomodate a greater programming effort, which will be dependent upon how efficiently we can integrate advertising into our system.

DIAGNOSING CABLE SYSTEM FAULTS

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ABSTRACT

There is a lack of technical information within the industry. This is particularly true of material for technician training. The most effective tool with which to ensure the delivery of the highest quality pictures is a well trained technician.

The New York Commission on Cable TV has produced a video tape which simulates system technical problems. The tape does not establish optimum ratios of noise or distortion. It displays distortions at levels that allow easy recognition of specific problems and shows distortion levels at FCC and CRTC standards.

The paper will discuss the tape, its uses in training, and the techniques used in its production.

BACKGROUND

For nearly five years the staff of the New York State Commission on Cable Television has traveled throughout the state utilizing a specially equipped test van in a program of testing and evaluating cable system performance. In that time over 300 tests of operating systems have been conducted. The Commission's Telecommunications Division staff has become acquainted with many cable system technicians and in the process of evaluating system performance has, coincidentally, evaluated many technicians.

The Commission has sponsored three major technical seminars which have attracted more than 350 technicians. Additionally, six regional seminars have been conducted with over 150 technicians attending. After each seminar a critical evaluation of the program has been done to determine the effectiveness of the seminar in terms of technical levels for future seminars.

In filling positions in the Telecommunications Division, the Civil Service Department administered written examinations to determine the abilities of applicants for the positions. One of the positions is equivalent to that of a chief technician in a large cable company; the other, that of a senior technician, capable of headend, trunk and feeder maintenance. Questions for the examination were solicited from the cable industry, manufacturers, and training directors of various companies. Additionally, use was made of questions published as a result of the SCTE 300 Project. In addition to operational and maintenance questions, a section of each examination was devoted to basic electronic theory. The results of these examinations were carefully studied. It was concluded that, despite an entrance requirement for the examination of a minimum of three years experience, many of the candidates earned failing, or near failing, scores.

In June, 1977, at the third annual New York Commission technical seminar in Albany, the Commission exhibited a video tape constructed to graphically display some common cable system faults. The tape was brief and to the point. Many of the technicians who saw it realized that they had not known the difference between cross-modulation and co-channel or inter-modulation.

It was not difficult to conclude that there exists a great need for technical education. Here is an industry utilizing very sophisticated hardware and techniques for signal transmission. In an industry that demands broadband performance that makes baseband video engineering look like childs play, the equipment is often maintained by persons who do not have the slightest idea of how to apply Ohms Law and cannot recognize the most common cable system faults.

The above is not a completely fair assessment of the technical capabilities within our industry. There are many excellent people in cable. Virtually, all of them are self-taught. Fortunately, these

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* The views expressed in this paper are those of the author and do not necessarily represent those of the New York State Commission on Cable Television.

persons share their knowledge with others in seminars, at conventions, and in too few publications. It is unfortunate that, when sharing, the assumption is made that the audience is technically sophisticated. Our experience indicates that such is not the case.

If there is to be an indictment, it should not be of the technical personnel in cable system operation, or those few who are expert but cannot be everywhere. The educational system has not fully recognized the need for technical programs in cable, the industry has not been insistent in demanding good educational programs, and industry management has not been overly enthusiastic in its training efforts.

Having recognized the problem, it became our task to assist in correcting it. It is not the purpose of this paper to fix the blame, but to attempt to fix the problem. Regardless of the existence of technical performance standards at various levels of government and the enforcement thereof, the most effective tool to ensure optimum picture quality is a well trained technician. Having reached that conclusion, the decision was made to produce an audio-visual training aid which could be made available to cable system operators at low cost. Cassette video tapes appeared to be the most viable delivery method.

Industry Support

The production of the tape would have been delayed for many months had it not been for the enthusiastic support of the cable industry and manufacturers of test equipment.1/ The Society of Cable Television Engineers provided a grant to partially defray production costs. Tektronix, Inc. and Hewlett-Packard provided test instrumentation and a precision demodulator. Scientific-Atlanta, Inc. supplied a modulator for the RF television channel used. The New York Network production facilities were used to produce the studio pictures and to record the quad high-band master tapes.

Educational Goal

The video tape has been produced to graphically show various distortions and interferences common to cable television distribution systems. The tape offers suggestions with respect to poysible corrective actions that may be taken to reduce or eliminate the problem. To that end, each section of tape begins with severe distortion. Thus, the technician viewing the tape can clearly see the effects of the distortion on the picture. The various distortions are then reduced to ratios specified in two well known national standards.2, 3/ No effort was made to determine which standard is more appropriate, nor is any attempt made to determine the optimum levels of degradation. A large body of work has been done with respect to subjective picture evaluation and optimum distortion ratios. The thrust of this tape is to show what the distortions are and not what they should be. However, should the reader wish to delve into that subject, a short bibliography is appended to this paper for reference.

The narrative which accompanies the video presentation is not in precise engineering terms. However, it will not mislead the viewer. Having evaluated the technical level at which we find many cable system technicians, we have determined that precise technical terminology must give way to a clear understanding of the problems depicted.

Application of motion and "busy" scenes in the tape was deliberately limited. While it is true that few still pictures are broadcast, for purposes of clearly showing the effects of the various distortions, it was decided to concentrate on showing the distortions without a background which might interfere with the learning process.

The brief discussion of probable causes for the distortions depicted in each section of the tape does not include all possible sources of operational problems. To do so would require many hours of tape. The more common causes are briefly discussed with the view towards initiating some thinking in the troubleshooting process that will soon discover the problem source.

The tape may be used for enforcement in formal training sessions, or it may be offered to technicians for individual study. Of course, it would be best to have a knowledgeable person available to answer any questions which may arise as a result of viewing the tape.

1/ The use of various manufacturers products in the production of the video tape does not constitute an endorsement of those products by the New York State Commission on Cable Television.

2/ Federal Communications Commission Rules and Regulations, Sub-part K, Section 76.605.

3/ Canadian Radio and Telecommunications Commission, BP-24, Broadcast Procedures for Cable Systems with Augmented Channel Capacity.

The tape, in cassette form, will be available at reasonable cost from the Society of Cable Television Engineers.

Video Tape Program Sections

The video tape is segmented for ease in identifying various distortions and to provide the viewer with a standard test signal with which to adjust his television receiver for optimum performance. The segments are as follows:

a) Introduction and instruction on receiver adjustments using monochrome gray scale and NTSC color bars.

b) The broadcast television signal.

c) The baseband video signal.

d) Carrier-to-noise presentation.

e) Co-channel Interference.

f) Electrical Interference.

g) Hum modulation.

h) Intermodulation interference.

i) Ghosting and reflections.

j) Cross-modulation interference.

k) Video baseband distortions.

How we made the tape

The television baseband signals, whether from the live studio cameras or from a film chain, were split at the respective camera output; one signal being fed to the studio switcher through a video delay line, the other through the mod/demodulator combination. Figure I shows the interconnection of the various devices. Of course, the devices were not simultaneously connected to the signal path.

Receiver Set-up

The first two sections of the tape deal with the proper set-up of the viewers television receiver. The user is "talked" through the monochrome set-up utilizing a standard five step gray scale. We chose to leave nothing to chance in the color section. The correct color name of each bar was keyed over its respective bar. The user is then "talked" through the appropriate adjustment of the color controls on the receiver.

Broadcast Television Signal

The television broadcast channel bandwidth is displayed as the ideal curve from the FCC broadcast rules. A brief discussion of the method of broadcasting the signal follows. The channel is then presented as it is seen on a spectrum analyzer.

The baseband video waveform is depicted showing the video waveform contained in the FCC broadcast rules. This is followed by a view of a waveform monitor. A brief discussion follows regarding what the synchronizing pulses are intended to accomplish.

Signal-to-Noise Ratios

Noise at various ratios was added at RF at the output of the modulator. This simulates a single channel being added to a broadband system. The noise added was essentially "white" over the frequency range of 40 to 300 MHz. The noise generator output was fed through a step attenuator to control injection levels.

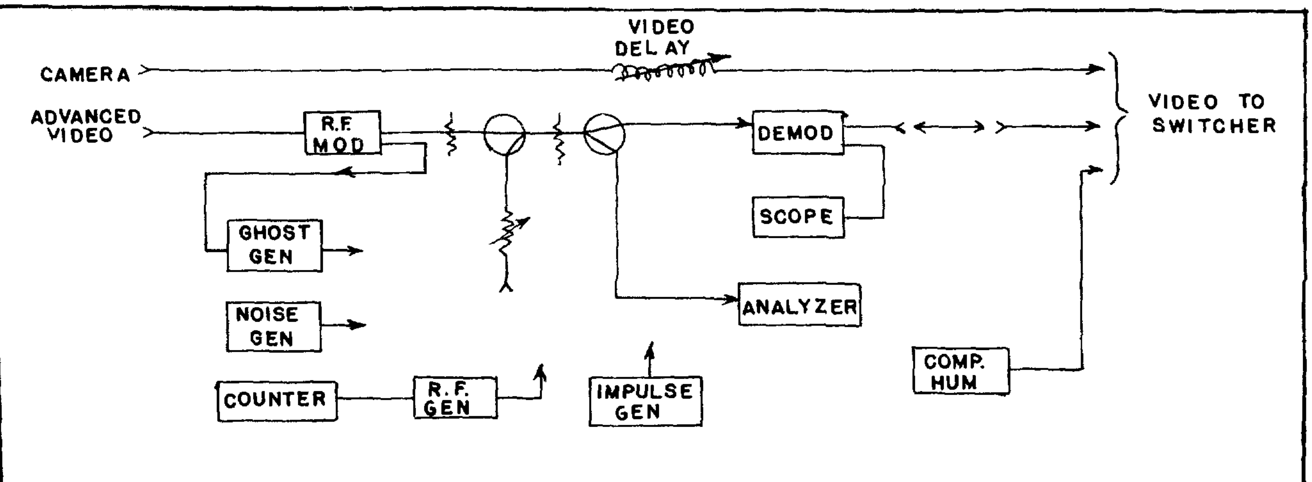


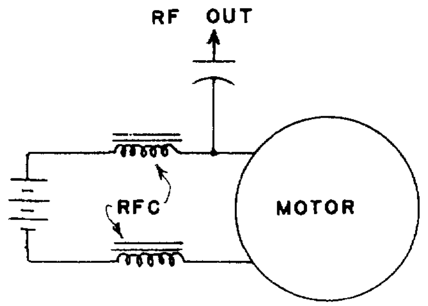
FIGURE I - EQUIPMENT LAYOUT

Co-channel Interference

The generation of co-channel interference required both a stable TV channel modulator and a precise, stable and easily controlled sine wave generator. The generator was expected to maintain 10 to 20 kHz off-sets for the period required to show both the effect on a TV picture of the interference and on a spectrum analyzer display. The purpose of showing both plus and minus co-channel was to alert the technician that the width of the interfering co-channel bars and the direction of movement through the picture was a clear key to the identification of the interfering station, without the use of a spectrum analyzer.

Electrical Interference

Display of electrical impulse noise required that a special circuit be devised to generate fast rise-time random electrical pulses. The circuit of Figure II solved the problem. No attempt was made to specify the absolute levels of interference, since noise of this type is very difficult to measure. In any event, the test equipment owned by the average cable system cannot measure the peak power of these pulses.



IMPULSE NOISE GENERATOR

FIGURE 2

Hum Modulation

Depicting hum modulation presented a unique problem. Present production video switchers are not designed to accommodate non-composite video inputs. Therefore, adding hum to the camera output would be meaningless, since the clamping circuits in the switcher would remove much of the added hum. Any residual hum would effectively be removed by the quad video recorder. Thus, any hum added at the switcher input, or camera output, would not be present in any tape copies.

The solution appeared in the form of a sync and blanking adder commonly used in television broadcasting for the addition of composite sync and blanking to sweep generators in sweeping transmitter circuits.

Hum was introduced to the sync and blanking adder as a video signal. After addition of composite sync and blanking, the hum signal was mixed with a camera signal in the switcher. Since the sync contains no hum, the switcher clamp circuits and the video recorder correction circuits see clean sync and the hum on the picture remains untouched.

Intermodulation

The section on intermodulation does not attempt to show composite triple-beats. The single frequency discrete interfering signal has been defined and specified in FCC and CRTC regulations and in some state regulations. It is a discernable and measurable interference, thus it was chosen to be shown. The tape narrative discusses composite beats, but the complexity of the topic is beyond the scope of this tape.

The interfering signal is injected at RF as shown in Figure I and the demodulated pictures are then recorded. Several frequencies and levels are shown.

Ghosting

The Ghosting Generator shown in figure I is a simple RF delay line to which is fed an output of the modulator. A level of insertion of the delayed signal is chosen to clearly show the ghost. The narrative discusses various causes of ghosting and direct pick-up and the difference in appearance.

Cross-Modulation

Modern cable systems do not display cross-modulation until other severe intermodulation distortions have effectively taken the system out of service. The difficulty of producing cross-modulation in an amplifier without generating other spurious signals led us to simulate the effect.

Two video signals were introduced at the video switcher input. One was locked to studio sync, the other was a "wild track". The wild track was mixed with the locked signal to produce the cross-modulation effect. Thus the tape shows video cross-talk rather than cross-modulation.

Video Distortions

The video tape shows the effects of two baseband video related problems which can be caused by signal processor design or alignment, and by filters, i.e.: bandpass, bandstop or cross-over filters in bi-directional systems.

Poor frequency response at the processor or antenna, or "suck-outs" on cable, may reduce the color carrier to a point where the color on receivers is low or "washed-out". The effect on the received picture is shown by introducing a baseband processing amplifier into the video from the demodulator and reducing the chroma information.

Chroma/liminance delay distortion, or "funny paper" effect, is generated and displayed on a receiver. No attempt is made to show measured chroma/luminance delay distortions.

A Tektronix Chrominance/Luminance Delay Corrector was inserted in the baseband video path, then misadjusted to show the effects of such delay distortions on the received picture.

A third form of baseband video distortion also can occur at RF in the signal processors. Should the RF visual carrier envelope be clipped or limited, the sync pulses will be distorted. Sync level reduction and ringing are the result of RF clipping of the visual carrier. This, in turn, causes receiver picture instability. The effects are discussed on the tape. However, the distortions are not shown.

Summary

The New York State Commission on Cable Television and the Society of Cable Television Engineers, in recognizing the need for technical education and training, have produced a video tape which is designed to assist the cable technician in recognizing the various distortions which may occur in cable distribution systems. The tape is designed to permit the trouble-shooting of a distribution system utilizing a very common and very sensitive test instrument-a television receiver.

The tape is intended to be used in formal training sessions, either as the primary topic or as a re-enforcement tool in structured lectures. It also may be used for individual study. Because it is in cassette video tape format, it is inexpensive and very portable. It represents a first step in what is hoped will be a major effort to train technicians. Distribution of the cassette tapes will be handled by the Society of Cable Television Engineers.

For in-depth discussions of the various topics discussed in this paper, the reader is referred to the bibliography which follows.

Acknowledgements are in order for the assistance and advise of the following organizations and individuals: The Society of Cable Television Engineers; the Staff of the State University of New York Television Network; the staff of the Telecommunications Division of the New York State Commission on Cable Television; Hewlett-Packard, Inc.; Scientific-Atlanta, Inc.; Tektronix, Inc.; and Daniel Whelan of the New York State Education Department Bureau of Educational Communications.

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FROM SATELLITE TO EARTH STATION TO STUDIO TO S-T-L TO MDS TRANSMITTER TO THE HOME; PAY TELEVISION COMES TO ANCHORAGE, ALASKA

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This paper presents the technical and operational considerations associated with a new, and unique, Pay Television service recently introduced into the Anchorage, Alaska, marketplace. The pay service incorporates the delivery of various programming sources via satellite, earth station design, studio origination system design and operation, interconnection of the studio with the distribution medium via point-to-point microwave (studio-transmitter-link), and the delivery of the pay product to the subscriber in the single family dwelling via the common carrier facilities of a Multipoint Distribution Service (MDS) microwave station. System design parameters and daily operational procedures will be discussed in depth as well as the first wide-scale utilization of a MDS facility to serve the private home marketplace with a pay channel.

It was at the NCTA convention in Chicago that Telecommunications Systems, Inc. (TSI), a Baltimore based communications and consulting engineering company, operating its own Multipoint Distribution System (MDS) properties, reached a preliminary agreement with two individuals who were committed to the idea of bringing a quality, premium programming package to Anchorage, Alaska. The TSI role was to be general technical consultants, systems designer, overall supervisor of equipment installation as well as start up, and to assist with the initial retail marketing program.

Along with the usual technical challenges that such a project presents, bringing Pay Television to Anchorage, Alaska also traversed some sticky political problems which I will just briefly mention throughout the course of this paper because of their intrinsic value to any pioneer bold enough to do a number of things first within a short time period.

The first chore was to arrange for the receipt of programming material. The first technical challenge came during the design of the earth station facility itself. Visions, Ltd., the pay programmer, had established its offices in an industrial park in the center of the municipality of Anchorage. It was their desire to locate the earth terminal adjacent to their offices which would also contain their studio complex. Because RCA Alascom had, over the years, utilized terrestrial microwave communications systems throughout the State of Alaska, we were not able to frequency coordinate a receive antenna for the desired location because of its proximity to downtown Anchorage. Parabolic dishes as large as 12 meters could not be utilized. Rather than forfeit the promotional benefits of a centrally located earth station clearly visible to all of the Anchorage, population, Visions elected to utilize an Antennas for Communications (ATC) CH-14M conical horn antenna. This would be the first known application of a conical horn antenna for Pay Television purposes anywhere. The antenna is of one-piece fiberglass, with a cloth radome, and measures approximately 37 feet from top to bottom. The diameter of the horn is 14 feet. The manufacturer provides the following specifications relative to the CH-14M:

Gain - 43.5db at 4GHz
Frequency Range - 2-20GHz
Noise Temperature - typically 2°K @ 4GHz
(not including Galactic noise)
Design Windload - 125 mph

It was determined that the horn reflector antenna would perform at the lowest side lobe levels of any type of parabolic antenna. Additionally, the horn reflector antenna will perform at the lowest wide-angle side lobe levels thereby permitting frequency coordination of the earth station in downtown Anchorage despite the neighboring terrestrial microwave systems operated by RCA Alascom.

Visions decided to establish a system capability so that a full programming package inclusive of Home Box Office, Madison Square Garden, and WTCG/Channel 17 could be provided to their potential subscribers. Unfortunately, the Home Box Office footprint from the primary satellite, RCA SATCOM II, had the poorest signal strength in Alaska. Minimum system design objectives of 50db ("clear day" signal-to-noise ratio at the video output) and a carrier-to-noise ratio of 12db at the receiver input were established. To satisfy these objectives as well as provide for "worst case" conditions, a 48°K parametric preamplifier, manufactured by AIL, was selected; as a backup, a GasFET low noise amplifier with a noise temperature of 90°K was also selected. Three Microdyne receivers, one tunable and two fixed, were selected for the purpose of being able to handle a minimum of two channels simultaneously with backup capabilities.

On July 15, 1977 attorneys for Visions, Ltd. filed their earth station application with the Commission.

Up to this point, I have not mentioned the method of distributing the signal to the potential subscribers subsequent to receipt of the programming material via the satellite. After all, there isn't a cable system within 200 miles of Anchorage and, of course, little time to build one. The owners of Visions had considered the possibility of building a cable system but abandoned the idea because of time and cost factors as well as the fact that broadcast signals are readily available off-the-air to the home from the three commercial television stations and the PBS station located within Anchorage. Having been introduced to the capabilities of MDS, Visions had earlier embarked on an analysis to determine if MDS could fulfill their needs as the distribution medium for their programming package. Their investigation came at a time when MDS technology was advancing rapidly and lower cost receivers were being introduced by several manufacturers that would permit the private home marketplace to be economically served by MDS; at least this conclusion held true for Anchorage, Alaska. The Anchorage population is ideally located for service by MDS. Its 200,000 plus population all reside on a relatively flat piece of land approximately 10 miles in radius having a high soil content of peat. Peat keeps the foliage in the area to a minimum; well below roof level in most circumstances. The MDS operator in Anchorage had located his transmit facility on a nearby mountain thereby placing his transmit antenna over 2,000 feet above the average terrain of the Anchorage metropolitan area but only 8½ miles from the population centriod. Adequate signal-to-noise ratio (S/N) could be obtained at receive sites incorporating the lower cost MDS down-converter/antenna as the following path loss analyses indicates:

Parameter	Receive Antenna Gain (db)	
	16	20
Operating Freq. (MHz)	2154.75	2154.75
Free Space Path Loss-8.5 miles (db)	122	122
Transmission Line Loss(db)	1	1
Field Losses/Fade Margin	5	5
Antenna Gain		
Transmit	16	16
Receive	16	20
Net Path Loss (db)	96	92
Transmitter Power (dbm)	40	40
Received Carrier Level(dbm)	-56	-52
Receiver Sensitivity (dbm; 8db noise figure)	-98	-98
S/N Ratio (db)	42	46

The output power of the transmitter was later to be increased to 50dbm in order to provide service to that segment of the Anchorage population located within "holes" or shaded areas. The MDS transmitter would also later be interconnected with the Visions studio by an 11GHz studio-transmitter-link utilizing a Farinon transmitter/receiver. The STL path is approximately 8 miles.

Having filed its application to construct an earth station and having obtained the air-time from the MDS operator in Anchorage, the next major task was to determine programming so a studio may be designed providing the capability to construct a high quality premium programming package. The emphasis was on "live" premium television. The Anchorage population previously had little access to "live" programming from outside of Alaska. Most near-real-time events were tape delayed; even Monday night football. Network programming was provided on a delayed basis anywhere from one to three weeks depending on the particular network involved. Therefore Visions chose to construct a programming package that was truely unique and not necessarily an alternative based upon the obvious deficiencies of the local Alaska braodcasters when compared to the "lower 48" broadcasters. Another significant consideration was the Anchorage time differential with regard to events occuring in New York City, Las Vegas, or California. Anchorage is five hours earlier than Eastern Standard Time and two hours earlier than Pacific Standard Time. Therefore it was decided that the greatest flexibility in the construction of a truly high quality programming package was to provide the capability for taping the incoming program material for retransmission at the most convenient time period for the viewer in Anchorage. After obtaining the necessary taping permissions, HBO would be seen at the same time in Anchorage as it is elsewhere; namely, the prime 6:00pm to midnight period. "Live" events, which may be originating in Madison Square Garden at 8:00pm New York time, could now be shown "live" in Alaska at 3:00pm, Anchorage time, without the necessity of preemption.

The Visions desire for a high quality programming package containing a mix of all available product dictated the capability which their studio complex required. Seven (7) Sony VO-2800 video tape recorders/playback machines were utilized as the heart of the origination center. All seven machines would be automatically pre-programmed and controlled for all functions including record and playback by a Digitrol II microprocessor. To best explain the design and the capability of the system, I will describe to you a typical programming day. The Visions program guide for Friday, December 30, 1977, listed the following program menu for the day:

	12:30 pm	Scream Theatre "The Human Monster"
(LIVE)	2:30 pm	NBA Basketball New Orleans Jazz vs. N.Y. Knicks
HBO	5:00 pm	"Part 2 Sounder"
	7:00 pm	"Inside the NFL"
	8:00 pm	"Birch Interval"
	10:00 pm	"A Clockwork Orange"
	12:30 am	"Casino De Paris"
	2:00 am	Visions Blockbuster "Dog Day Afternoon"
	4:00 am	Visions Blockbuster "Shampoo"

The above programming schedule would be accomplished in the following manner:

EVENT	DESCRIPTION
#1	"Scream Theatre" consists of locally originated product procured by Visions ahead of the scheduled playback date. In this case "The Human Monster" is a monochrome "oldie" transcribed on 3/4" u-matic cassettes (2) and is 1 hour and 13 minutes in length. Each cassette has been cued for automatic start, transfer and rewind functions. The microprocessor will automatically bring the movie up at the desired start time of 12:30pm.
#2	At approximately 1:43pm the "stand-alone" operation ends and the microprocessor automatically switches from the end of the movie (prompted by a cue tone) to a Systems Concepts character generator. The character generator formats the screen into three fields. The top third of the screen contains the Visions logo and displays time, temperature and date. The middle field of the screen contains the AP newswire. (In Alaska, only the broadcast newswire is available.) The lower third of the screen contains pre-programmed alphanumerics usually of a promotional nature. Background music comes up automatically with the character generator. The background music is originated by a reel-to-reel, automatic reversing Sony tape deck.
#3	At 2:30pm the operator utilizes a combination of routing switchers and a special effects generator to fade out the character generator and place onto the line the Madison Square Garden NBA basketball game at the appropriate moment as determined visually by the operator. The basketball game is being received "live" by the satellite feed, transponder 22, from the fixed frequency Microdyne receiver and redistributed without time delay.
#4	Remove the stand-alone product, "The Human Monster", from the VTR's.
#5	Place blank stock in VTR's #1, #2, #3, and #4.
#6	At 3:00pm, Anchorage time, the Digitrol II has been pre-programmed to begin recording the regular evening HBO program menu. Without interrupting the NBA basketball game which is going out over-the-air "live", the operator fades into the beginning of the HBO program. Please keep in mind that it is now 3:00pm Anchorage time and 5:00pm, Pacific Standard Time. The Visions receiver is tuned to transponder 20 which relays the HBO material on Pacific Standard Time. Throughout the recording cycle, the microprocessor will place the cue tones on the adjacent audio track at the proper time in order to facilitate the pre-programmed playback. At the end of the first record period of VTR #1, approximately 4:00pm, the Digitrol II will automatically switch to VTR #2 during the vertical interval without recording interruption.
#7	Basketball game ends about 4:30pm Anchorage time. The operator fades the game to "camera black" and switches in the character generator, with background music, which I described previously.
#8	At 5:00pm, the Digitrol II microprocessor, having been pre-programmed to playback the VTR's containing the evening's HBO program material in sequencial fashion, begins playback of the first HBO movie of the evening which starts with the playback of VTR #1. At approximately 5:00pm, continuous recording of the evening's HBO material was transferred to VTR #3. At exactly 5:00pm, Anchorage time, the first HBO movie of the evening automatically switched onto the LINE and the character generator was removed automatically.

During the balance of the evening, the recording/playback sequence of HBO continues automatically and unattended as follows:

Anchorage Time	Playback	Record
6:00pm	VTR#2	VTR#4
7:00pm	VTR#3	VTR#1
8:00pm	VTR#4	VTR#2
9:00pm	VTR#1	VTR#3
10:00pm	VTR#2	VTR#4
11:00pm	VTR#3	VTR#1
12:00 midnight	VTR#4	-
1:00am	VTR#1	-

EVENT	DESCRIPTION
#9	The last HBO program for the evening will end at approximately 1:30am Anchorage time. The Digitrol II will sense the end of the movie (playback sequence) and automatically place onto the LINE the character generator, with background music, again.
#10	The operator will remove all cassettes from the VTR's.
#11	Two "Visions Blockbuster" movies are to be shown for the balance of the evening. This product consists of locally originated material procured by Visions ahead of the scheduled playback date for their stand-alone operation. The operator will pre-program the Digitrol II to start the first movie at 2:00am and start the second movie at 4:00am, Anchorage time. The cassette tapes which the movies have been transcirbed onto had previously been cue toned for the automatic, stand-alone, playback operation. At this point, the operator goes home and the studio will be unattended for the balance of the evening.
#12	At approximately 5:52am the last Visions stand-alone movie ends and the Digitrol II automatically replaces the movie with the character generator output, with background music, as described previously.

In addition to the recording/playback flexibility described above, the Visions studio incorporates the capability of monitoring each satellite transponder of interest, signal processing by a Microtime 2020 PLUS Time Base Corrector and Image Enhancer, test signal generation, cross pulse monitor, audio record/playback mixing and level control, and titling. Additionally, the studio has the capability of constructing its own promotional messages by utilizing two VO-2850 VTR's with an editor off-line. These promotional messages can be pre-programmed and sequenced with the regular program material as desired.

As mentioned previously, the link between the Visions studio and the mountain MDS transmit site is provided by an 11GHz point-to-point system owned and operated by the MDS common carrier. The system features redundant Farinon transmitters and receivers with built-in alarms.

The MDS transmission facility contains, besides the Farinon receivers, two Electronics, Missiles, and Communications (EMCEE) 10 Watt transmitters and a single EMCEE 100 Watt amplifier. An automatic transfer/control device provides the ability of switching from one 10 Watt driver to the other 10 Watt unit in the case of malfunction. The output of the 100 Watt amplifier is connected to an Andrew, high gain (16db), cardiod transmit antenna, which is approximately 50 feet away from the amplifier output port, via waveguide. The transmit antenna is down tilted 3^{o} from the local horizontal and elevated approximately 25 feet above ground level in order to best serve the Anchorage community.

The MDS low-cost receivers being utilized by Visions have been obtained from several different manufacturers. Depending upon the manufacturer, each receiver has its own physical characteristics and technical performance differences as well. Most sources provide a low-cost receiver featuring a "free-running" oscillator which, characteristically, drifts as the ambient temperature changes. These type of receivers utilize some type of manual tuning device located at the subscriber's television set. Another manufacturer, however, provides a crystal-controlled MDS antenna/down-converter at a similar low price which is particularly attractive because of the natural hostile environment which prevails in Alaska. Although Anchorage itself does not experience radically cold temperatures, the mast mounted down-converter will encounter temperatures as low as $-30^{o}F$ occasionally during the winter season. Of course, on the other hand, the temperature during the summer (July & August) seldom exceeds $65^{o}F$. It was easily determined that the down-converter would be exposed to daytime/nighttime temperature variations of 30^{o} on a regular basis.

Whomever the manufacturer, the antenna/down-converter is required to provide the following:

- . . enough gain/receiver sensitivity to deliver a quality signal
- . . the receiver be quickly and easily mounted to either the existing Yagi mast or a mast which the installer provides
- . . be of a profile that will not offend the esthetic value of a residential neighborhood

Additionally, because of the cold temperatures, minimum sunlight during the day in the winter time, and the high cost of skilled labor, it is necessary that the receiver be designed in such a manner to permit rapid attachment to the structure as well as swift interconnection from the receiver output to the television set. Visions is experiencing an average of 5 private home installations per day per installer during the winter months. Except for multi-family dwellings and non-standard installations, all installers are dispatched singularly without helpers. An average time for a standard installation is 45 minutes; once the installer has the antenna mounted, he connects the output of the down-converter to its power supply located at the subscriber's television set or some other convenient location. Next, the installer orients the antenna in order to obtain the maximum signal strength. In the case of the "free-running" oscillators, the installer will go through the procedure of both "coarse" and "fine" tuning the picture.

The ability of MDS to serve the private home marketplace within those cities out of the Top Fifty is a necessary ingredient required to produce a viable operation for the Pay TV entrepreneur because of the relatively small multiple family/hotel marketplace which are normally found in these smaller cities. The Visions idea of serving the moderate size city with a high quality programming package via MDS is not only unique but mandatory. The churn must be kept to a minimum in order for the system operators in smaller marketplaces to be viable. It is hoped that the highest quality of programming available today, accompanied with a competitive price structure for the service, will result in high retention rates.

Earlier in this paper I mentioned that part of the programming mix was to consist of WTCG/ Channel 17. Visions has yet to offer any portion of WTCG to its subscribers, as of the date of this paper, because of the lack of the necessary permission from the Commission to serve Alaska. The result of this regulatory delay caused Visions to procure additional stand-alone product during its initial start up period. Also, during the installation of its earth station, in October, 1977, because of its centrally located position, which I mentioned previously, local Anchorage news media provided Visions with excellent coverage of the delivery of the conical horn antenna by ship from Seattle and the subsequent antenna raising activities. This early public exposure, although beneficial from a marketing point of view, created some discussion at the Alaska Public Utilities Commission (APUC) as to whether the MDS operator as well as the pay programmer, Visions, fall into the category of a "public utility", as defined by Alaska law and, if so, whether both companies should be regulated. Although the question, as of the date of this paper, had yet to be put aside, the APUC investigations and discussions relative to the matter did not prevent Visions from going on-the-air for revenue purposes on 1 December, 1977.

With a mass media advertising campaign consisting of radio spots and newspaper ads the weekend preceeding 1 December, 1977, Visions began installing subscribers at an initial rate of 10 per day. By the end of February, 1978, Visions had installed 1,500 subscribers and enjoyed a waiting list of well over 1,000; the delivery rate of receivers did not complement the number of early subscribers.

It will be another six months before a significant amount of data will be available to determine the success of the Anchorage venture. However, by conventional standards, Visions has succeeded in establishing a viable pay operation in Anchorage, Alaska; from satellite to the subscriber via MDS.

IMPROVING RELIABILITY OF DROP WIRE CONNECTIONS

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ABSTRACT

One of the weak links in CATV systems for years has been the 59/U drop connectors when they have been installed outdoors. This can be shown by the analysis of service call records and more recently thousands of radiation reports.

This presentation describes new connector concepts that are designed to reducing these problems. These concepts are applied to a new connector which has improved mechanical and electrical parameters with simple installation procedures for all weather conditions.

What is the cost of a more reliable system and improved reception to the subscriber?

How can the technical trade-offs be converted into dollars? The method of assessing the economics of this new connector are also discussed.

INTRODUCTION

The demand for improved performance of subscriber drop "F" connectors is steadily increasing. The CATV Industry is now utilizing the full bandwidth of the system. Frequencies outside the standard TV/FM band are now regularly being used for additional channels in the forward and reverse directions. RF integrity in the mainline hardware and co-axial cables in the past has been greatly improved to overcome egress and ingress problems. The weak link in the present CATV network remains in the drop wire "F" connector, and since this is an equally important connection the requirement to maintain integrity must be met.

This paper deals with improvements to the "F" connector aimed at overcoming this weakness. This paper is divided into the following sections.

1) Historical Background
2) Design Philosophy
3) Improved Connector Assembly
4) Cost Analysis

HISTORICAL BACKGROUND

One way to evaluate system problems is to maintain records that can assist in the review of past experiences and problems. Our radiation monitoring system has certainly indicated a problem in the connector area.

Figure 1 represents the data tabulated for over 3,000 cleared radiation problems that have been detected by this monitoring procedure. The chart is divided into six sections as follows:

a) Drop Hardware
Consisting of connectors, splices, matching transformers, tap-off devices, and drop cable. Seventy percent of the data reported in this section was due to connectors alone.

b) Feeder Cable
Consisting of connectors, splices, sheath breaks, and other problems that could be encountered on trunk and distribution cables. The problems reported in this section were mostly with connectors and splices.

c) Passive Equipment
Consisting of splitters, multi-taps, wrong value multi-taps, matching transformers and other passive equipment. Problems reported were mixed with no definite trends.

d) Active Equipment
Consisting of amplifiers and mostly reflects problems with levels set too high and loose housing lids.

e) Illegal Hookups
Consisting of illegal extensions to FM/TV sets, or neighbour's sets with 300 ohm lead or other unauthorized connections with unshielded cables.

f) Subscriber's Equipment
Consisting of internal and external antennas that are still hooked up and extensions made with 300 ohm lead or other unshielded cable to move the receiver. Approximately 60% of this section was due to subscribers antennas still hooked up.

The radiation monitoring system has indicated approximately 1,455 connectors requiring repairs. Radiation monitoring equipment has been operating in eleven of Canadian Cablesystems' licensed areas for three years now with one radiation receiver installed per vehicle for each one hundred and fifty kilometers (94 miles) of plant.

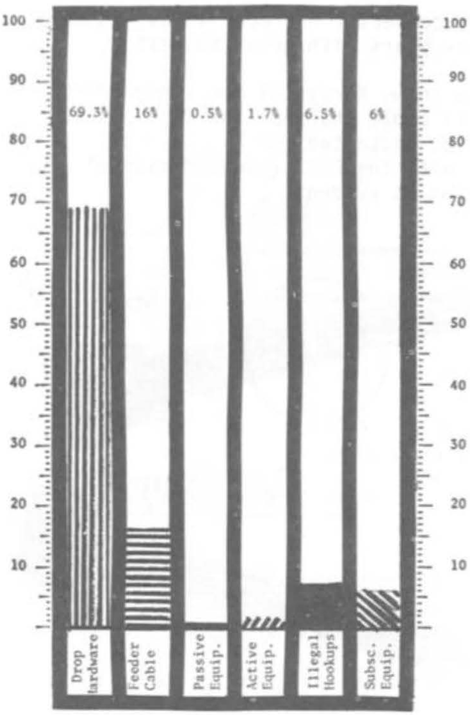

Figure 1
ANALYSIS OF RADIATION MONITORING PROBLEMS

In 1972 the demand for a more effective shielding for drop wire steadily became important to meet the requirements of systems with signals in the midband. The cable selected by Canadian Cablesystems is of the aluminum tape surrounded by braided shield. Specifically the construction is an aluminum-polypropylene-aluminum-laminate tape, 0.0017" thick applied longitudinally with an overlap encasing the polyethelene dielectric with an additional braid with 55% of shielding. See Figure 2.

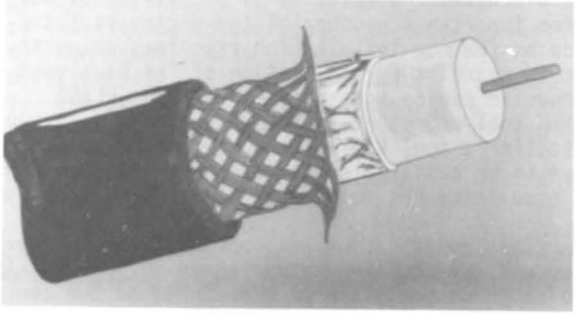

Figure 2
SINGLE BRAID CABLE WITH FOIL

Standard F59 connectors did not make proper connections to the aluminum foil; they caused more radiation and ingress problems than we had experienced with our 95% braided cables. This problem is specifically related to the mandrel forcing the foil back or through oxidized contact materials and not making a proper connection.

A second problem of concern for many years has been that of weatherproofing connections. Weatherproof boots and other methods that have been used for many years have not been very successful. I am sure you have seen corroded connections at your line tap-offs. Totally sealed drop connection in the underground environment has been another problem not yet solved.

In search of a solution to this problem, one must examine the fundamentals.

DESIGN PHILOSOPHY

Proper operation and reliability of a connector depends to a large extent, on how well it can perform while withstanding specified environmental conditions. The following are some of the most commonly encountered environmental factors to be considered:

a) High and low temperature
b) Thermal shock
c) Mechanical shock and vibration
d) Rapid change in pressure
e) Humidity
f) Bacteriological growth and fungus
g) Presence of corrosive atmosphere (1)
h) Salt spray
i) Dust and sand
j) EMI - electromagnetic interference (2)

Not all of the above factors may be encountered in the same system, but sometimes a combination of several of them may create extremely critical situations. In addition to the environmental factors other requirements must be considered in this design:

a) Compatibility with other fittings and hardware of the system.
b) Easy installation with minimum effort and inexpensive installation tools.
c) Producible at a reasonable and justifiable cost.
d) Exhibit a high reliability level and be readily maintainable.

IMPROVED CONNECTOR ASSEMBLY

In 1954, Eric Winston of Jerrold Electronics developed a solderless and easy to install connector call the F59 as shown in Figure 3.

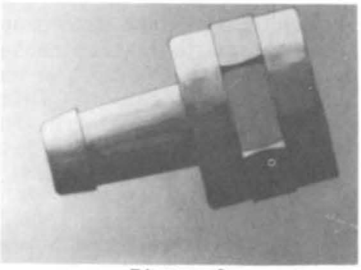

Figure 3
STANDARD CONNECTOR

This connector has been, and is still being used with a great deal of success for RG59/U type braided cables. However, when the foil braided cables came along, the standard "F" connector could not be installed without the foil being pushed back under the braid and jacket as shown in Figure 4.

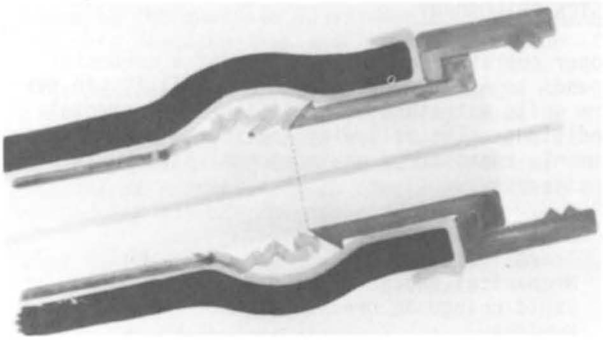

Figure 4
FOIL DISTORTED WITH STANDARD F59

In an attempt to correct this problem, Albert Stirling of Stirling Connectors, Canada, worked with Canadian Cablesystems to improve this problem. A solution was modifications to the standard F59 as shown in Figure 5, that consists mainly of slots in the mandrel and a flare inside the mandrel so that the connector may now slide over the foil and under the braid.

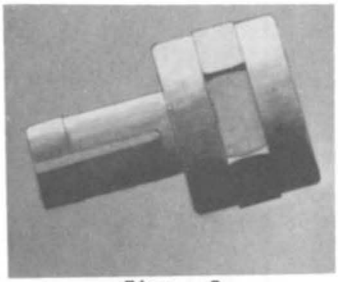

Figure 5
SPLIT MANDREL CONNECTOR

The foil could now be seen inside the connector's swivel nut fitting, assuring a good connection. One additional feature of this modification is that with a standard size crimp ring the mandrel will collapse down onto the foil making a mechanical and electrical connection, ensuring continuity of the shield conductor. The mechanical cable retention is increased by an additional 15 lbs. This improved connector has been in use in cable systems for three years with great success.

Figure 6 shows X-rays of the standard F59 installed on a foil cable that has the foil pushed back and the braids distorted for a couple of inches, contrasted with the F59S (slotted mandrel where no distortion is evident.

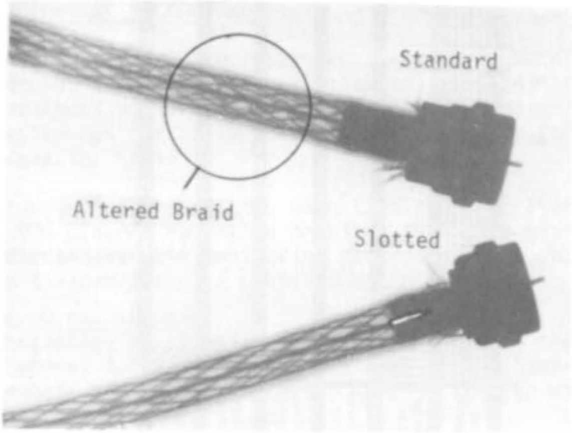

Figure 6
X-RAY COMPARISON OF STANDARD AND SLOTTED F59

The slotted mandrel connector also shows shielding improvement for bonded foil cables through the improved electromechanical connections. However, this does not solve our moisture ingress problem.

The combined efforts of Cablesystems Engineering and Amphenol of Canada Ltd. continued with the activity in attempting to solve the moisture ingress problem through the development of a waterproof F59S connector.

In the preceding section, the design philosophy which should be considered in this development was discussed. Simplicity is identified as having prime importance because of the desire to introduce as few new installation practices or parts. For instance, the installation of the developed connector can be accomplished with the PL602 crimp tool and other standard tools found in your installer's tool kit. The number of parts that have to be handled is still three. This concept of simplicity has maintained an economical design.

The first modification was made to the connector body and the coupling nut as shown in Figure 7-①. Two neoprene seals ③ have been added to the connector. The Hex nut has to be changed to 1/2", to permit an increased shell size necessary to accommodate the addition of the seal inside the coupling nut. The seal is positioned inside the coupling nut (1) and (3) in order to maintain the same grounding contact of the shouldered contact (4) found in the standard F59.

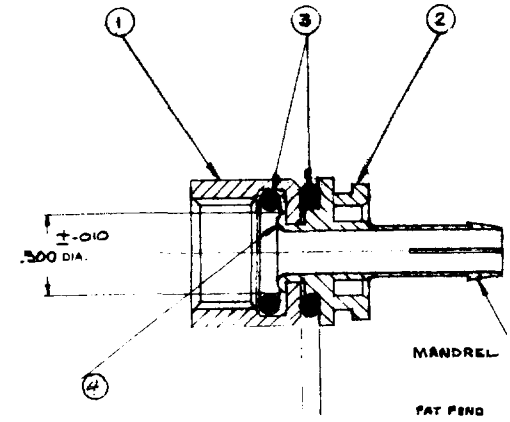

Figure 7
AMPHENOL WATERPROOF F59S

The addition of these seals waterproofed the connector, but they do not guarantee a seal from the body of the connector to the cable.

The next modification included the design of a sealing boot that could be easily installed on the cable and would slip over the body of the connector but would not interfere with the coupling nut. The body of the connector has an additional groove to accommodate the sealing boot shown in Figure 7-(2) This design approach allows the boot to remain on the connector during installation and disconnection. Three sealing rings are moulded into the inside surface of the boot so that proper sealing is achieved around the cable jacket. See Figure 8.

Critical properties must be considered in the selection of the material for the sealing parts. They must have:

a) Long-term weather adaptability
b) Non-solubility
c) Resistance to corrosive reagents
d) Non-adhesiveness
e) Flexibility at low temperatures
f) Low co-efficient of friction
g) Stability at high temperature

Neoprene was selected as the material most suited to these requirements.

Figure 8 shows the final version of the waterproof F59S with the sealing boot installed.

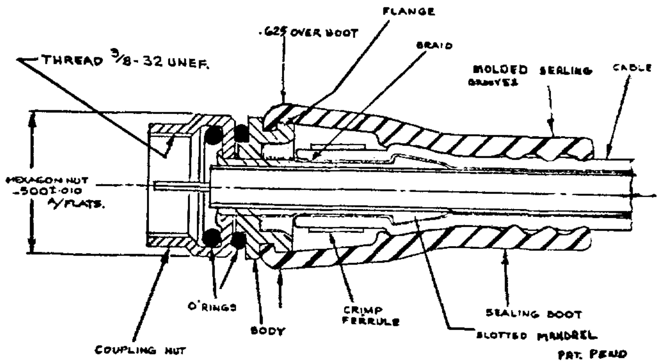

Figure 8
AMPHENOL WPF59S WITH WEATHER BOOT INSTALLED

After finalizing the requirements for the connector, and the basic electromechanical design criteria, a set of performance specifications were formulated. They are as follows:

Specifications for Waterproof F59S Co-Axial Connector

a) Electrical

i) Impedance - 75 ohm nominal.
ii) Voltage rating - 500 volts peak.
iii) Dielectric withstanding voltage - 1500 volts R.M.S.

b) Mechanical

i) Cable affixment - Crimp Ferrule 0.135" wide.
ii) Cable retention - 35 lb. maximum pull test of cable from connector.

c) Environmental

i) Operating temperature range -40°C to 85°C.
ii) Vibration - Mated connectors will withstand vibration to MIL-STD-202 Method 204 (Test Condition D) (20 G. peak) over a frequency range of 10 to 2000Hz. 12 times with connector mounted in the horizontal position and vibration in the vertical mode for a period of 8 hours.
iii) Corrosion - Salt spray test in accordance with MIL-STD-202 Method 101 (Test Condition B) length of test 48 hours exposed to a salt solution concentrate of 5%.
iv) Water Pressure Seal - Mated connectors will withstand a differential water pressure of 5 P.S.I. No electrical degredation after testing.

d) Materials

i) Connector body - Zinc diecast.
ii) Coupling nut - Zinc diecast.
iii) Crimp Ferrule - Brass.
iv) Plating - Cadmium Plate (All metal parts).

v) Sealing boot - Neoprene Per MIL-G-1149B Type 1-Class 1.
vi) O'Rings - Neoprene Per MIL-G-1149B Type 1-Class 1.

Prototype connections have been built to those specifications and have been subjected to and have passed the following tests:

a) Continuity - mating connector coupling nut and center conductor to cable.

b) Dielectric withstanding voltage - 500VDC for 5 seconds mated.

c) Waterproof - tested at 5 lbs. per square inch pressure - 60 days.

d) Physical vibration at -30°C - 20 G. peak 20-2KHz, 8 hours, mated followed by tests a), b), and c).

e) Physical vibration at 50°C - 20 G. peak 20-2KHz, 8 hours mated followed by tests a), b), and c).

f) Accelerated thermal aging at 85°C - 50 hours unmated.

g) Accelerated thermal aging at -55°C - 50 hours unmated followed by tests a), b), and c).

h) Cable retention test - 30 lbs. axial pull force, followed by tests a), b), and c), mated.

i) Salt spray - as Per MIL standard 202, Method 101 (Test Condition B) length of test 48 hours exposed to a salt solution concentrate of 5%.

COST ANALYSIS

In order to compare the costs a model system with 20,000 subscribers will be used. The assumptions in developing this model are as follows:

a) Cost of standard F59 with weather boot--0.20
b) Cost of waterproof F59S--0.50
c) Cost of service calls, overhead including truck, tool and expenses per call--10.85
d) Service calls due to drop problems average 7.5% of subscribers per year with 80% of these calls due to connectors.
e) Assumed service call reduction of 50% is proposed for the waterproofed drop connectors.

Therefore, fixed cost for standard F59 will be:

$$FC_S = 20{,}000 \times (a) = 20{,}000 \times 0.20 = \$4{,}000$$

Variable cost per year will be:

$$VC_1 = 20{,}000 \times (d) \times (c) = 20{,}000 \times 0.075 \times 0.80 \times 10.85 = \$13{,}020$$

Proposed waterproof F59S will be:

$$FC_P = 20{,}000 \times (b) = 20{,}000 \times 0.50 = \$10{,}000$$

Variable cost per year will be:

$$VC_2 = 20{,}000 \times (d) \times C \times 0.50 = 20{,}000 \times 0.75 \times 0.80 \times 10.85 \times 0.50 = \$6{,}510$$

Figure 9, indicates a breakeven point at the 12th month period and a cost savings in the second year. If some of the assumptions in this model do not agree with your experience, try your own maintenance costs.

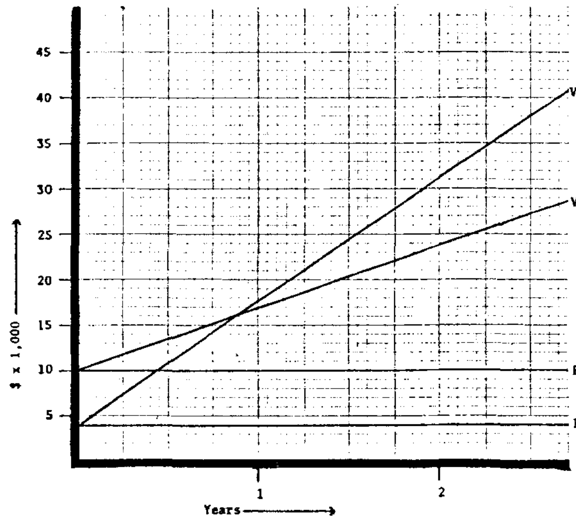

Figure 9

COST COMPARISON

The above calculations have not considered depreciation, tax savings and present value since technical departments do not normally base their evaluations and comparisons on that type of calculation. However, I would like to model another analysis based on present value calculations. The data in developing this model is as follows:

a) The cost of a standard F59 with weater boot--0.20
b) The cost of waterproof F59S--0.50

Therefore, the incremental investment in a 20,000 subscriber system = 0.30 x 20,000 = $6,000

c) Service calls due to drop problems average 7.5% with 80% of these calls related to

connector problems. The assumption that the proposed connector reduced connector related service calls by 50% as a savings of 20,000 x 0.075 x .80 x .50
= 600 calls per year is realized.

d) Cost of service calls, overhead including truck, tools and expenses per call--10.85

Therefore, yearly savings = 600 x 10.85
= $6,510

e) Tax rate 48%
f) Capital cost allowance 30%
g) Present value return rate 12% = i
h) Life 10 years = N
i) Annuity factor $\frac{1}{i}\left[1 - \frac{1}{(1+i)^N}\right]$
j) Tax shield = tax rate x capital cost allowance rate (CCA) / (CCA + return rate)

$$\text{Tax shield} = \frac{\text{tax rate} \times \text{capital cost allowance rate (CCA)}}{\text{CCA} + \text{return rate}}$$

The net present value (NPV) can be obtained from the following formulae:

$$\text{NPV} = \text{Investment} \times [1 - \text{tax shield}] + \text{yearly savings} \times [1 - \text{tax rate}] \times \text{annuity factor}$$

$$\text{Therefore, NPV} = -6{,}000 \times \left[1 - \frac{0.48 \times 0.30}{0.30 + 0.12}\right] + 6{,}510 \times (1 - 0.48) \times 5.65$$

$$= \$15{,}184.38$$

Therefore, the waterproof connectors after recovering their increased costs provide a net saving of $15,184.00.

Now, if we wish to determine how many service calls per year we need to breakeven on the incremental cost of investment over a 10 year period; i.e. set the net present value to 0.

NPV = investment x (1-tax shield) + (# service calls saved) x cost of service calls x (1-tax rate) x annuity factor

$$0 = -6{,}000 \times \left[1 - \frac{.48 \times .3}{.3 + .12}\right] + \#\ \text{service calls} \times 10.85 \times (1 - .48) \times 5.65$$

$$0 = -3{,}942 + \#\ \text{service calls} \times 31.88$$

Therefore, # service calls = 123

Therefore, if more than 123 or 0.6% of subscribers have service calls due to connector problems then the extra cost of the new connector is covered and a net savings is realized in the 20,000 subscriber model system.

I must point out that the above models do not take into account radiation problems, since the subscribers normally don't call for a service call when their drop wire connector is exceeding FCC/DOC standards and regulations. Radiation problems have not been recorded in our service call analysis; therefore additional expense allowances must be added to the above results for the added costs. Based on data recorded and indicated in Figure 1, this percentage can be quite high in the first couple of years when clearing radiation problems.

I believe that this Cost Analysis helps to indicate that improved drop line connections are required and can be justified.

SUMMARY

The CATV operators' primary goal is to manage profitable systems with a minimum of downtime. From the data taken to date and with these design concepts, we have demonstrated that predetermined electromechanical design objectives can be achieved in addition to practical and inexpensive goals.

ACKNOWLEDGEMENTS

The author would like to acknowledge the assistance of A. Stirling of Stirling Connectors, Canada and Jim Stokes and Kam Boutrof of Amphenol Canada Ltd. Appreciation is also extended to my colleagues at Cablesystems Engineering for their contributions in this project.

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INTERFACING CABLE TELEVISION AND BROADCAST SUBSCRIPTION TELEVISION

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One of the primary technical advantages with coaxial cable television for telecommunication purposes is the cable system's technical compatibility with most of the newly developed communication systems in addition to existing communication systems now being given renewed priority consideration as a result of the public demand for premium subscription programs.

Cable television systems may be confronted with some technical compatibility problems if required to carry both the Broadcast Subscription Television (BSTV) station's premium and "free" programs. While there may not be a channel capacity problem in offering more than one type of premium program, there are compatibility problems involving the delivery of BSTV and cable premium programs over the same cable system.

By Public Notice dated November 15, 1977, the Commission identified seven (7) BSTV systems which had received "advance system approval." These systems are not compatible. Moreover, there are applications presently pending before the Commission for a waiver of "the one BSTV station to a community" rule. If this rule is waived, this would further complicate the compatibility/interfacing problem between cable and BSTV. Cable systems may choose to carry other over-the-air premium signals with little or no technical interfacing problems. This is evident from system carriage of: HBO's programs via satellite, and Multipoint Distribution Service (MDS) signals. This paper will only focus on premium BSTV program carriage on cable systems.

BSTV premium carriage on cable systems presents varying degrees of technical problems for all cable systems since all the BSTV systems involve encoding both the video and audio. This paper will address some of the technical, compatibility problems between various types of cable systems and specific hypothetical encoding and decoding techniques which could be proposed by BSTV stations, how interfacing can be accomplished, circumstances under which piracy can occur, and what can be done to minimize piracy.

History

On February 10, 1955, the Commission adopted a Notice of Proposed Rule Making in Docket 11279, FCC __-___, __ FCC 2d ___, in response to a petition filed by Zenith Radio Corporation and Teco, Inc. (proponents of the "Phonevision" subscription television system); Skiatron TV, Inc. (proponent of the "Subscriber-Vision" subscription television system); and other television licensees and permittees. While no specific proposals for rules were contained in the Notice, it did include questions of law and facts designed to ascertain whether the Commission should adopt rules to authorize television stations to transmit programs paid for on a subscription basis. This Notice defined BSTV simply as the transmission of programs intended to be viewed only by those who pay a charge.

On May 23, 1957, the Commission adopted a Notice of Further Proceeding in Docket 11279, FCC 57-530, 22 F. R. 3758, announcing that it had statutory authority to authorize the use of television frequencies for subscription operation if it found that such a decision would be in the public interest. However, the comments submitted per the February 10, 1955 Notice failed to provide an adequate basis for concluding either that subscription television should or should not be authorized. Therefore, in the NPR of May 23, 1957, the Commission was persuaded that trial demonstrations would be indispensable and invited comments to aid it in deciding the conditions under which trial operation should take place.

On October 17, 1957, the Commission adopted a First Report and Order in Docket 11279, 23 FCC 532, 16 RR 1509, detailing the basis for the statutory authority and also announcing that the Commission was prepared to accept applications for authority to conduct trial subscription television operations prescribed therein. A Third Report adopted in 1959 amended the First Report in three important respects:

(1) it allowed trial of a specific subscription TV system in only one market instead of up to three;

(2) it allowed only one system to be tried in a market instead of more than one; and

(3) it precluded operators of trials from requiring the public to purchase equipment (a question left open in the First Report). 1/

After a five-day en banc hearing before the Commission on February 23, 1961, the first BSTV application (filed on June 22, 1960, under the terms of the Third Report) was granted to RKO General Phonevision Company (then known as Hartford Phonevision Co.,), licensee of UHF station WHCT, Hartford, Connecticut. The Commission's WHCT authorization permitted a three-year trial operation of subscription television using Zenith Phonevision equipment. 2/ The operation commenced on June 29, 1962. Then on May 21, 1965, the authorization was extended for a period of three years or (if it occurred sooner) until such time as the Commission terminated the outstanding rule making and "enters an order with respect to the authorization."

Zenith Radio Corp., manufacturer and holder of the patent for Phonevision equipment, and Teco, Inc., patent licensee of Zenith, filed a joint petition for further rule making on March 10, 1965 to authorize nation-wide subscription television which, among other things, contained detailed information about the first two years of the Hartford trial.

On March 21, 1966 the Commission adopted a Further Notice of Proposed Rulemaking and Notice of Inquiry in Docket 11279, 7 RR 2d 1501, in which the Commission stated, inter alia: (1) that it "...has statutory authority to authorize subscription television on a permanent basis..." and the court decision in the Hartford case is not limited to upholding the Commission's authority to authorize trial operations only, and (2) that subscription television constitutes "broadcasting within the meaning of Section 3(o) of the Act and therefore, it is not a common carrier service. Moreover, aside from deciding the two issues above, the Commission invited comments on other questions such as:

(1) Should Subscription Television be Permitted in All Markets and Should There be a Limitation on the Amount of Time that Stations May Devote to Subscription Broadcasting?

(2) Should Subscription Television be Limited to UHF Stations or Otherwise Limited with Respect to Stations?

(3) Should Subscription Television be Permitted Over More Than One Station in A Community, and if So, Should Such Stations be Permitted to Broadcast Subscription Programs Simultaneously?

(4) Should Subscription Television be Limited to a Single Technical System?

The Commission for the first time enlarged the BSTV proceeding, and invited comments pertaining to wire or cable subscription television. Questions raised regarding a hypothetical situation for a community with no off-the-air TV signals and a single cable system were as follows:

(1) Would it be necessary to have built-in antennas in the decoders attached to sets of subscribers?

(2) Would a single decoder attached to the cable system which delivered the unscrambled signal to subscribers suffice?

(3) If so, what arrangement for collection of subscription fees could be made?

(4) Would the rules on carriage of signals of local stations over cable systems apply to carriage of BSTV premium programs?

On December 12, 1968, the Commission concurrently adopted a Fourth Report and Order and Third Further Notice of Proposed Rulemaking in Docket 11279, 3/ wherein the Order established a nationwide, over-the-air subscription television service, and with the exception of technical standards, adopted rules governing the BSTV service. This Order also discussed the question of carriage by cable systems of BSTV signals and announced that although the Commission is not presently requiring such carriage, it is issuing the instant Third Further Notice inviting comments

1/ The Third Report, adopted March 23, 1959, amended the First Report in some respect, and otherwise "readopted and reaffirmed it. 26 FCC 265, 16 RR 1540a.

2/ In Connecticut Committee Against Pay TV v. FCC, 301 F2d 835 /23 RR 2001/ (D. C. Cir.) cert. denied, 371 US 816 (1962) the United States Court of Appeals for the District of Columbia Circuit affirmed the action of the Commission in authorizing this trial.

3/ FCC 68-1174, 15 FCC 2d 466 and FCC 68-1175, 15 FCC 2d 601, respectively.

on a proposal to require it. The Third Further Notice proposed that cable systems operating within a BSTV station's Grade B contour carry both the coded and uncoded programming of the BSTV station exclusive of decoding the coded signal at the cable system headend. 4/ This proceeding also proposed the cable system carriage of BSTV station to within the station's Grade B contour.

Recently, the Commission issued a Notice of Proposed Rulemaking and Inquiry in Docket 21502, FCC 77-848, __ FCC 2d ___ calling for comments on the possible effect multiple BSTV service would have in a given community. The Third Further Notice in Docket 11279 and the recent Notice and Inquiry in Docket 21502 considered in conjunction with the growing market of pay cable premium programming in the country, indicates to some extent, the degree of the non-technical problems and issues the Commission must resolve in considering whether to require carriage of the encoded premium programming of BSTV stations by cable systems. However, the focus herein will be on the technical compatibility problem of BSTV with the various types of cable systems.

Types of Cable Systems

For the purpose of examining specific types of cable systems in conjunction with BSTV stations, we will assume that the Commission has a rule requiring cable systems to carry BSTV stations coded programming if the cable system serves a community located within the BSTV station's Grade B contour.

Technically, there are three basic types of cable television systems. They are: (1) the Single-Cable-Non-Converter cable system; (2) the Multi-Cable-Switcher-System; and (3) the Converter-Cable-System. The Single-Cable-Non-Converter system attaches directly to a matching transformer for connection to the back of the subscribers receiver at the 300 ohm input antenna terminal. This system has a maximum TV channel capacity of the standard 12 VHF television channels. Moreover, the cable operators normally remove the off-air-antenna when a cable connection is made (see Figure 1).

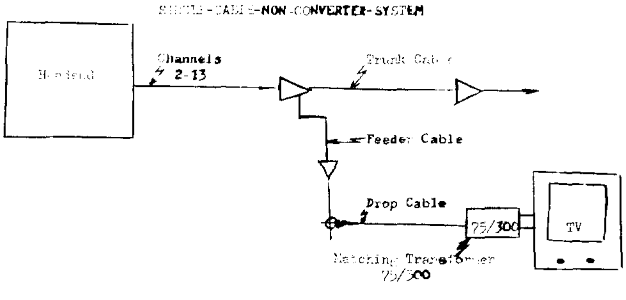

FIGURE 1

The Multi-Cable-Switcher-System utilizes two or more cables on the distribution plant up to the subscriber's terminal, where a switch is then installed containing a single 75 ohm cable output which is attached to a matching transformer containing a 300 ohm twin lead that connects to the back of the subscribers receiver at the 300 ohm input antenna terminal. This system channel capacity depends on the number of distribution cables, with a maximum of 12 TV channels per cable. The majority of Multi-Cable-Switcher-Systems are dual cable systems with a capacity of 24 TV channels selected from "A" and "B" cables using a switch at the back of the subscriber receiver. (See Figure 2)

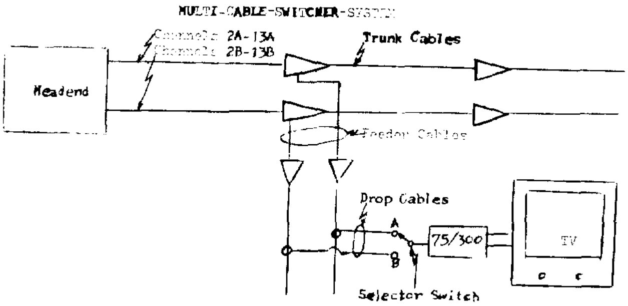

FIGURE 2

The Converter-Cable-System is a system utilizing a converter at the subscriber terminal which attaches to the receiver preempting the television set tuner. This system's TV channel capacity is normally in excess of 30 depending on, the type of converter and/or the number of distribution cables utlized (see Figure 3).

4/ Issues pertinent to this paper are BSTV rules codified in Volume III, Part 73, Section 73.641-73.644 which state: (1) BSTV is a broadcast service; (2) BSTV stations licensed to or proposing to operate in communities located wholly within the Grade A contour of five (5) or more commercial TV stations, including the applicant station, would be eligible to receive BSTV authorization; (3) only one BSTV station will be authorized in a community; (4) BSTV stations are also required to broadcast at least the minimum amount of uncoded programming required to conventional TV stations pursuant to Section 73.651 of the Rules; (5) BSTV stations are required to provide premium programming service to all requesting persons within the station's Grade A contour; and (6) comply with an interim system equipment and performance approval procedure pending further amendment of the rules establishing a type acceptance procedure.

CONVERTER-CABLE-SYSTEM

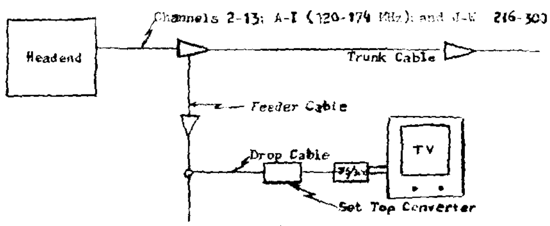

FIGURE 3

These three types of cable systems and the combination of the Multi-Cable Switcher and Converter-Cable-System constitute the vast majority of cable systems in operation throughout the country. Therefore, interfacing of BSTV premium programming over cable systems will be limited to a discussion of these three systems.

Types of BSTV Premium Systems

By Public Notice dated November 15, 1977, FCC-91486, the Commission identified seven (7) BSTV systems which had received "advance system approval." 5/ As indicated earlier, these systems are not compatible. Using three imaginary, hypothetical premium systems, the non-compatibility characteristic of premium systems can be demonstrated. These hypothetical systems were constructed by extracting technical data from available data submitted to the Commission. The propriety of the material would not allow the author to specifically discuss any of the type approved systems.

These premium systems are not intended to describe any of the BSTV systems which are pending or which have secured system approval from the FCC. These are imaginary, hypothetical systems described here to focus on the problems confronting cable systems if the Commission were to require carriage of BSTV stations premium programming. The premium systems are described in a manner to include a close replica of a premium system which may be utilized by a BSTV station, Multipoint Distribution Service (MDS) station and/or a premium satellite signal (e.g. HBO). These imaginary systems will be identified as STV-Model-1, 2, and 3 premium systems.

5/ The systems are: (1) Zenith Radio Corp.-Phonevision; (2) Blonder-Tongue - Number 4745; (3) Feature Film Service, Inc. - Model FFS-2000; (4) Oak Industries, Inc. - Model I; (5) Pay Television Corp. - PTV System 3; (6) Teleglobe, Inc. - Number 410; and (7) System Development Corp. - SDC Pay TV System. One other system is pending from MELCO which proposes to only scramble the audio, and the Commission has denied one system filed by Tanner Electronics.

STV-MODEL-1

The MODEL-1 system encodes by cutting the conventional 525 line television picture into many horizontal segments of a specific number of lines each. Alternate number of line segments are continuously shifted back and forth horizontally, while the divisions between these specific number of line sigments randomly shift their position producing a visual effect of picture segments moving up and down vertically. The combination results in a satisfactory breakup of the picture with little intelligibility. In addition the video signals are transmitted with the black and white inverted similar to a photographic negative.

Video segments not shifted in the coding process are shifted in the decoding process, while segments that are shifted in coding are not in decoding making the video coding process at the transmitter complementary to the video decoding at the receiver.

The audio accompanying the encoded video is scrambled by shifting the audio in frequency. The decoding of the audio is accomplished by shifting the audio back to its original frequency.

The video coding is varied from program to program. Therefore, the coding pattern information needed by the decoder will likewise change from program to program. The coded broadcast signals cannot be decoded without the combined use by each subscriber of the following combined steps:

> A "Pressure" signal is transmitted over the air as part of the MODEL-1 broadcast and both subscribers and non-subscribers can receive this "Pressure" signal. However, decoding does not occur until a ticket, which is mailed to all subscribers, is inserted into the decoder. (See Figure 4)

STV-MODEL-2

The MODEL-2 system multiplexes discrete spectrum bandwidth for transmission of visual, chrominance, barker aural, digital control, and digital aural signals. The visual, chrominance, and barker aural information are transmitted together on a single channel as is standard for NTSC color transmission. However, a second grouping of signals is utilized for transmission of a digital, frequency-shift keyed signal containing a stream of specified bit serial binary data and a digital frequency-shift-keyed signal containing a stream of specific bit serial binary data.

The MODEL-2 system frequency-division multiplexes the frequency-shift keyed signals with the visual portion of the television signal in a single broadcast TV channel. The carrier frequency of the amplitude modulated visual signal, frequency

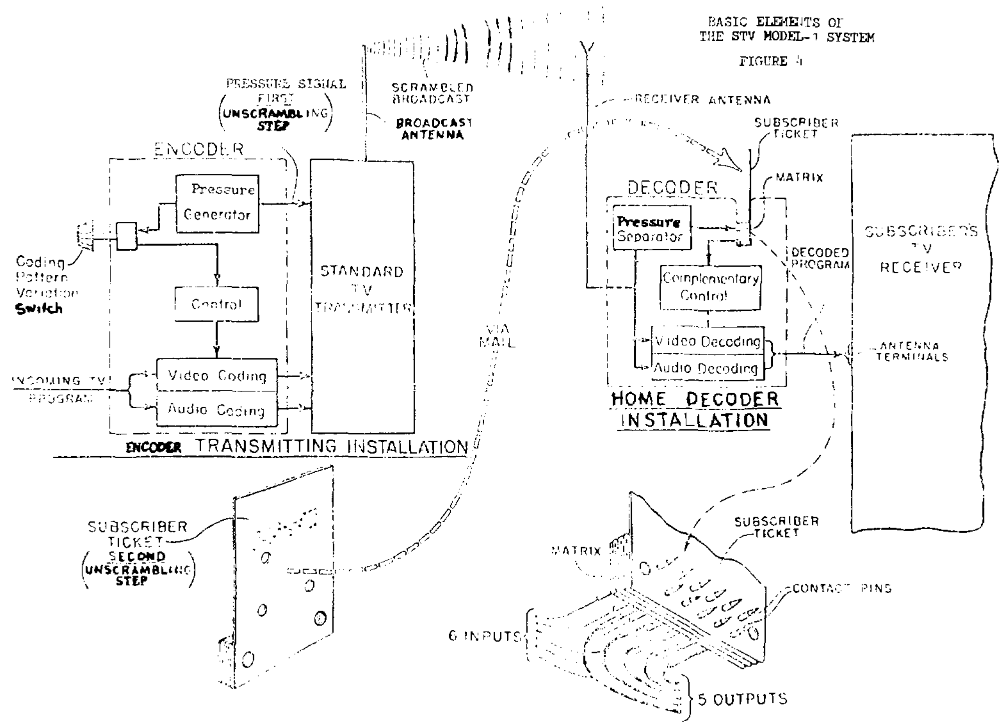

FIGURE 4

modulated control signal, frequency modulated aural signal, and phase modulated chrominance signal all occupy the same bandwidth, but at different center frequencies.

Separate discriminator and synchronous detector circuits in the receiver's intermediate frequency amplifier and detector circuit boards sort out the four signal components. This method of overlapping AM and FM signals is identical in principle to recently proposed methods for broadcast of stereo on the AM standard broadcast band channel.

The STV-MODEL-2 decoder attaches to the subscriber receiver 300 ohm antenna lead, and to a standard 4 prong telephone socket. When a subscriber requests service, he depresses a button on his decoder. Automatically his decoder places a telephone call to the broadcaster's facility, and sends data over the telephone network containing the subscriber's account number and requested code.

A computer at the broadcaster's site stores this data and the telephone call is terminated. At the appropriate time, the broadcaster sends the control signals to unlock the subscribers decoder box and the otherwise scrambled audio and video on the television receiver is restored. When the broadcaster no longer sends the account code of a particular decoder box in his control signal, the decoder automatically locks up and only a coded picture can be viewed.

STV-MODEL-3

The MODEL-3 system employs a method which uses an interference signal impressed on the normal composite video signal, including the intercarrier audio signal, in a phase relationship to the horizontal sync pulses reducing the amplitude of the sync pulses and simultaneously increasing the video content between pulses.

A receiver seeing this encoded signal will attempt to achieve horizontal lock on the highest instantaneous signal level detected which is now in a new position from a normal television broadcast signal transmitted in the United States. The randomness inherent in video information will add to the receiver's difficulty in achieving horizontal lock and the resulting picture is unwatchable because of improper lock and horizontal tearing.

The decoder, which attaches to the subscriber's receiver, 300 ohm antenna terminal, is activated by simply turning a switch on the unit to the premium mode.

Interfacing

If the Commission were to require cable systems to carry the BSTV stations premium program, the Commission should also require that the BSTV station premium system comply with the technical, transmission standards codified in Section 73.682 of the Rules for conventional television broadcast stations. Moreover, a premium system receiving "system approval" from the Commission, does not necessarily mean that when the system is installed and operated by the BSTV station, the station will comply with the transmission standards codified under Section 73.682 or 73.644. Section 73.644 of the Rules contains technical standards applicable to BSTV stations equipment and system performance.

Existing cable systems have been designed and built to carry television station signals meeting the requirement of Section 73.682 of the Rules. Cable systems carrying stations meeting the standards under Section 73.682 require that the cable system be designed and built in accordance with certain specifications, utilizing specific types of active and/or passive equipment in order to comply with the cable television technical standards codified under Section 76.605 of the Rules.

While it appears relatively easy for the premium signal out of the BSTV station subscriber's decoder to violate Section 73.682, especially in reference to overmodulating the audio, an assumption will be made that the three hypothetical premium system transmit signals in compliance with Sections 73.682 and 73.644 of the Rules. 6/ However, it must be emphasized that if the Commission decides to create separate technical standards for BSTV premium signals out of the decoder, no requirement pertaining to cable system carriage of BSTV premium signals should be instituted without ascertaining the impact on cable systems.

Therefore, assuming that the STV-MODELS-1, 2 and 3 premium systems meet the standards under Sections 73.682 and 73.644, one can then proceed to examine how these imaginary premium systems can be carried on the three types of cable systems identified above.

The operator of the Single-Cable-Non-Converter (S-C-N-C) system can carry any one of the three types of hypothetical premium systems with little or no technical difficulty. BSTV premium signals can be carried and unscrambled on a cable system in two ways: (1) unscrambling the signal at the headend; or (2) unscrambling at the subscriber's terminal.

6/ While this assumption is being made for these three hypothetical premium systems, field tests are the only true way to determine compliance. In this regard, it is noted that the Commission has authorized only eight BSTV stations. Of these stations, only the Newark, New Jersey, and Corona, California stations have actually begun operation. In addition, there are at least 23 applications pending for premium authorizations in at least fourteen other communities. Many of these pending applications must be designated for comparative hearing since the "one-to-a-community" rule has made them mutually exclusive.

S-C-N-C Headend

Unscrambling at the cable system's headend for distribution purposes can be accomplished two ways. The first is to unscramble the BSTV premium signal at the headend utilizing a decoder compatible with the BSTV station's encoder and redistributing the unscrambled BSTV station's premium signal on a vacant VHF channel to all subscribers. This approach involves the least expense to the cable operator in purchasing new equipment. However, it may not be the simplest technique to administer since it appears under this approach, that the cable operator may have to pay the BSTV program supplier a flat, bulk rate for the premium program, possibly, based on his number of annual subscribers. However, this unscrambling technique is the least expensive regarding equipment installation, and it appears to pose the least technical problem, since all three of the hypothetical premium systems can interface with S-C-N-C cable systems when unscrambling is accomplished in this manner. (See Figure 5)

S-C-N-C CABLE SYSTEM

(Where the BSTV premium signal is unscrambled at the headend and distributed unscrambled to all subscribers).

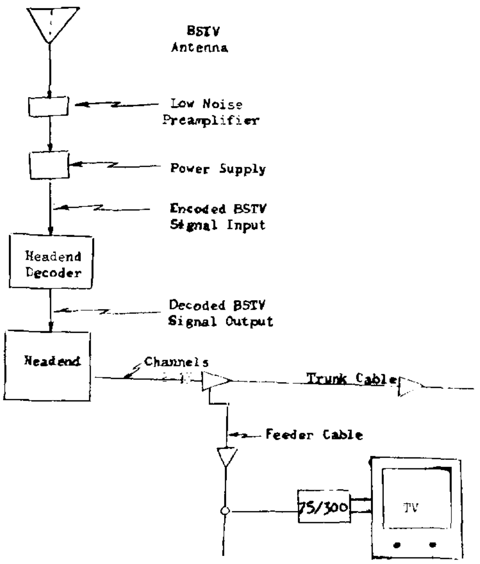

FIGURE 5

This approach has the disadvantage of possibly forcing all S-C-N-C subscribers to pay for and receive the BSTV premium programming whether he wishes to subscriber or not thereby exempting the cable subscriber from the freedom of choice available to non-cable subscribers.

The second way unscrambling at the cable headend is accomplished is by unscrambling the BSTV premium signal at the headend using a decoder compatible with the BSTV station encoder, and then the S-C-N-C operator recodes the premium signal and converts the BSTV premium signal to a vacant VHF channel for distribution to only interested subscribers. This technique appears to be more practical, but it also appears to be more costly. (See Figure 6). When the S-C-N-C

S-C-N-C CABLE SYSTEM

(Where the BSTV premium signal is unscrambled and then rescrambled at the headend for distribution to subscribers equipped with a decoder).

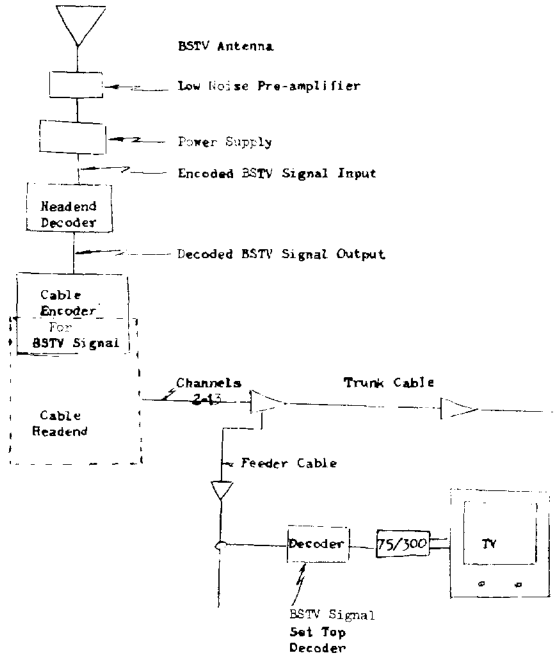

FIGURE 6

operator uses this approach, there are two rate and service approaches used by the BSTV station, codified in the form of affiliate agreements, involving the expense for purchasing, installing, and maintaining the encoder/decoders equipment on the cable system. These two approaches can be seen from an affiliate agreement between one operating BSTV station, WTVG-TV, and a cable system operating within the station service area. Under the first approach the BSTV licensee offers the cable system an affiliate agreement for a license fee of $5.00 or 50% of the premium program service charged per month, per subscriber depending on which fee is greater. This agreement specifies that the cable operator will purchase and install the necessary decoding devices and maintain total subscriber service for the BSTV premium program subscribers. Moreover, when the cable operator wishes to use a decoder other than that used by the BSTV station, the station will own the master headend decoder, and the cable operator will own all other headend components.

The second approach involves the same license fee, however, the BSTV station has a service agreement for cable operators, including those offering other premium program services, which state that the cable operator "...will purchase and install the necessary headend equipment to receive and deliver..." the BSTV station premium programs, "...and provide all installations, servicing and disconnects." The BSTV station will market, and provide the appropriate decoder for each BSTV subscriber on the system. The BSTV station will pay the cable operator $7.50 per installation and $2.00 per month per BSTV subscriber. In the event the BSTV premium program supplier sells his program to a BSTV subscriber, who is passed by the cable operator and not a cable subscriber, the BSTV supplier will pay the cable operator $10.00 for the BSTV premium program installation and $3.00 per month for servicing of the single channel. If the BSTV subscriber becomes a cable subscriber, the BSTV station will then pay $2.00 per month as above. In this case, the cable operator remains a contractor for installation/maintenance.

S-C-N-C Subscriber Terminal

The second way the S-C-N-C cable system can carry and unscramble a BSTV premium signal is at the subscriber terminal. In this way, the S-C-N-C operator can install the appropriate cut-to-channel receiving antenna, low noise preamplifier, and power supply at the cable system headend, converts the BSTV encoded signal to a vacant VHF channel and deliver the coded BSTV signal to all subscribers. Subscribers wishing to view the BSTV programs must be furnished a decoder which is compatible with the BSTV station's encoder. As indicated above in the second approach of the BSTV/cable system affiliate agreement, the BSTV station will market and provide the appropriate decoder for each BSTV subscriber on the system. Moreover, the BSTV station will also pay the cable operator for servicing, installation, and maintenance of the BSTV decoder equipment. This approach centralizes all servicing and maintenance at the subscriber's terminal by affording the cable operator almost exclusive jurisdiction. Having this jurisdiction, can possibly eliminate subscriber complaints resulting from allowing parties, other than the television repairman and the cable system technician, to tamper with the subscriber terminal equipment.

Without addressing the legality of BSTV station/cable systems affiliate agreements, if the Commission were to require cable systems to carry BSTV premium signal placing a Grade B contour over the cable community, the Commission should simultaneously address the cable system access to and responsibility for the BSTV premium signal decoders. It is noted that the S-C-N-C and the Multi-Cable-Switcher-System (M-C-S-S), unless furnishing a premium unscrambled signal to all subscribers, will have no active auxiliary equipment attached to the subscriber receiver (See Figure 1 and 2, respectively). Therefore, a decision as to S-C-N-C and M-C-S-S operators' responsibilities for securing the decoders must be ascertained. Should the cable operator be required to purchase these decoders from the premium system manufacturer or BSTV station? Or, should the responsibility for the decoders fall on the BSTV station whose signal the cable system is required to carry. The S-C-N-C and the M-C-S-S systems can carry premium programming on his system without installing a decoder at the subscriber terminal. This technique involves the installation of traps at the non-premium subscriber's terminal. These traps can prevent a non-premium subscriber from receiving the premium programming being delivered, unscrambled, over the cable system.

Traps

A trap is placed in the cable drop, usually remote from the interior of the non-premium subscriber's home. In communities where the percentage of subscribers of premium programming is high, a trap system, theoretically, probably makes more sense. The trap is inexpensive, relatively easy to install and virtually maintenance free since it is not an active device but a passive one. It should be noted however that the trap only weakens the video signal, hopefully, so the non-premium subscriber cannot see it, and normally does nothing to the audio.

An economic disadvantage to using traps can be illustrated by the following example.

A cable system, with 10,000 subscribers 2500 of which are subscribing or would like to subscribe to the premium programming, must trap 7500 homes at a cost of approximately $7.00 per home (which is the average cost of the most inexpensive trap). Therefore, approximately $70,000 is needed to purchase and install the traps, and this amount must be invested before the premium channel is activated and a sale made. Therefore, in this example, the cost of a trap is approximately $21.00 per premium program subscriber based upon 25% saturation of homes connected to the S-C-N-C and/or M-C-S-S cable systems.

Aside from the economical disadvantage, traps can easily be physically damaged by non-premium program subscribers to pirate the signal. In addition, the installation of traps require a trained technician. However, since the non-premium program subscriber may not allow this technician access to the home, it is difficult to assess whether the trap has removed the premium signal from the receiver.

Signal Leakage

Regardless of whether the BSTV station or the S-C-N-C and/or M-C-S-S operator has responsibility for the decoders at the subscriber's terminal, there is a potential problem of signal leakage from the BSTV signal decoders. Presently, cable systems are plagued with the fact that television receivers are not well shielded from radiation of off-air-signals. This means that the receiver is capable of picking up a signal through the receiver's tuner and this undesired signal will cause interference to the desired cable signals utilizing these same off-air-channels. The S-C-N-C and/or M-C-S-S cable systems avoid this interference by utilizing channels on the system which are not utilized off-air in the area. Television receivers also radiate signals including the cable television signal, but this is not necessarily the responsibility of the cable operator. The cable systems' responsibility for cable radiation go up to, and includes, the equipment of the cable system at the subscriber's terminal designed to interface the drop cable with the subscriber's television receiver. Nevertheless, the cable system attempts to control radiation from the receiver by delivering a minimum visual signal level of 1 millivolt and/or 2 millivolts across a 75 ohm and/or 300 ohm terminating impedance, respectively, but below a maximum level such that signal degradation due to overload in the receiver does not occur.

If, however, radiation occurs at the point where the drop cable interfaces with the subscriber's receiver, the cable operator must take steps to insure that the maximum field does not exceed 20 microvolts per meter, 10 feet from the cable. (See Section 76.605(a)(12) of the Commission Rules).

However, with the addition of a decoder between the drop cable and the subscriber's receiver, cable systems may no longer be able to meet the cable radiation standards specified in Section 76.605(a)(12) since the cable operator may not control the decoder.

MULTI-CABLE-SWITCHER-SYSTEM (M-C-S-S)

The same problems pertaining to the S-C-N-C cable system would be involved with a M-C-S-S cable system and therefore will not be covered separately. However, there are more abstruse policy and technical compatibility problems pertaining to the Converter-Cable-System (C-C-S) as will be demonstrated below.

CONVERTER-CABLE-SYSTEM (C-C-S)

As can be seen from Fig. 3, the C-C-S system utlizes a set top converter as an input to the subscriber television receiver. The cable converter is a well shielded unit, containing among other things, a tuner which is utilized in place of the receiver tuner, which is not well shielded. The Converter-Cable-System is utilized primarily in areas requiring cable systems with large channel capacities, and/or in areas where a number of television broadcast stations furnish strong off-air signals which can be picked up by the television receiver absent the receiver's own antenna. There may be a few C-C-S systems providing subscribers with converters capable of receiving a premium channel, but not yet providing that programming. In such cases the C-C-S operator could simply unscramble the signal at the headend and deliver the signal to interested subscribers on a vacant premium channel. If however, the system is already offering a premium program service, adding the BSTV premium signal would involve the most difficult interfacing problems and the greatest equipment expense. Additional or modified equipment at both the headend and the subscriber's receiver would be necessary because of the type of decoders and converters currently in use. Most converters now in use only have circuitry capable of decoding one scrambled channel. Therefore, the addition of a BSTV premium signal would necessitate the addition of more unscrambling equipment at the headend and a second piece of equipment, the decoder, at the subscriber's terminal. (See Figure 7).

Carriage and unscrambling of a BSTV premium signal on a C-C-S system can be accomplished by unscrambling at the headend or at the subscriber terminal. Unscrambling at the C-C-S headend can be accomplished by either: (1) distributing the unscrambled BSTV premium signal on a mid- or super-band channel and furnishing interested subscribers with a special converter on a key and/or card which allow the subscriber to access the mid- or super-band channel containing the BSTV programming; or (2) unscrambling the BSTV premium signal and then rescrambling the BSTV station premium signal at the cable headend for distribution to subscribers equipped with a BSTV decoder in addition to the cable converter. Figure 7 indicates how the latter unscrambling method can be accomplished. The BSTV decoder must be placed in series with the cable converter. Moreover, the cable subscriber now becomes functionally dependent on the cable converter and the BSTV decoder. Admittedly, the BSTV decoder is transparent and is activated only when the decoder switch is tuned to the premium channel. It simply acts as a non-active passive device for all other channels distributed over the cable system. However, the subscriber's access to all television could depend on whether this BSTV decoder operates free of any malfunctions. In addition, the BSTV decoder, installed as depicted in Fig. 7, will increase the possibility of signal leakage from all channels, including the BSTV channel, passing through this decoder. While the typical decoder does not contain an oscillator capable of radiating a signal, it must be well shielded to preclude the cable signal from radiating, and simultaneously prevent off-air signals from infiltrating the cable signals to cause interference. Therefore, the problem facing the S-C-N-C and M-C-S-S operators in adhering to the cable technical standard specified in Section 76.605(a)(12) will also face the C-C-S operator. The decoder is equipped with 75 ohm input and output leads similar to the cable converter. The 75 ohm output of the cable converter is attached to the 75 ohm input of the decoder and the 75 ohm

CONVERTER-CABLE-SYSTEM AND BSTV PREMIUM DECODER

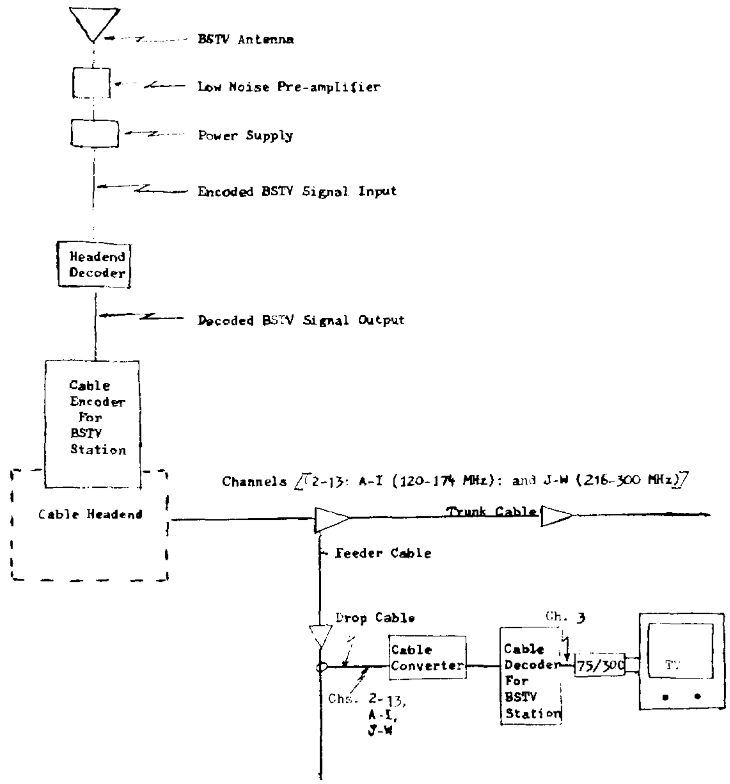

FIGURE 7

output of the decoder must be connected to a matching transformer which interfaces the 75 ohm decoder to the 300 ohm antenna terminal of the television receiver. Therefore, a cable subscriber wishing to view the BSTV premium program would tune the cable converter to the channel on which the BSTV signal is being distributed by the cable system thereby viewing a scrambled signal until the decoder is activated to unscramble the signal.

OFF-AIR RECEPTION OF BSTV SIGNAL BY CABLE SUBSCRIBER

Another alternative way to interface the BSTV premium signal with the cable system, is to install a separate BSTV station antenna at the cable subscriber terminal. (See Figure 8). This technique involves installing a UHF antenna at the subscriber terminal where the antenna output lead consists of a 75 ohm coaxial cable attached to a converter/decoder input jack. The Converter/Decoder unit which contains a converter and a decoder converts the BSTV, UHF signal to a vacant VHF channel, usually Channel 3, and the signal is unscrambled by the decoder in this unit and sent through the VHF output terminal. The converter/decoder VHF output terminal is a 75 ohm coaxial cable. This output lead can then be interfaced with the cable subscribers' receiver through an "A" and "B" switch connected to a 75/300 ohm matching transformer attached to the receiver antenna terminal. This technique allows the subscriber to receive both the cable system service which may include a pay cable channel and also receive the BSTV station premium programming over the same receiver. 7/ It does, however, call for a specific installation, maintenance, and service agreement between the cable operator and the BSTV station to avoid the possibility of having service delays or conflicts between the two services. The subscriber should in no way be caught between the two services when there is a malfunction or a complaint from a subscriber terminal.

It should be noted however, that since both services are using a converter, the converter's output channels may be identical depending on what off-air channel is vacant in the area. Therefore, the BSTV converter/decoder unit must furnish sufficient isolation to prevent reflections caused by open circuited or short-circuited subscriber terminals from producing visible picture impairments on the cable signals. 8/ It is suggested because of the close proximity of the two terminals that the isolation be in the vicinity of 50-60 db for the off-air BSTV system at the cable subscriber terminal. In addition, the BSTV system radiation must be substantially reduced so as not to cause interference to the cable system or any other receiver off-air reception. The cable system, as indicated above, must not radiate in excess of 20 microvolts per meter at a distance of 10 feet from the cable when utilizing channels between 54 and 216 MHz to distribute its programming. It should be pointed out that once this switch is installed and a

7/ There are other versions of this technique, for example, the BSTV station receiving antenna and a decoder could be attached to the receiver's UHF antenna terminal. However, the technique above is sufficient to address the interfacing problems.

8/ Cable systems are required to comply with Section 76.605(a)(11) regarding terminal isolation which states: The terminal isolation provided each subscriber shall be not less than 18 decibels, but in any event, shall be sufficient to prevent reflections caused by open circuited or short-circuited subscriber terminals from producing visible picture impairments at any other subscriber terminal.

OFF-AIR RECEPTION OF BSTV SIGNAL BY CABLE SUBSCRIBER

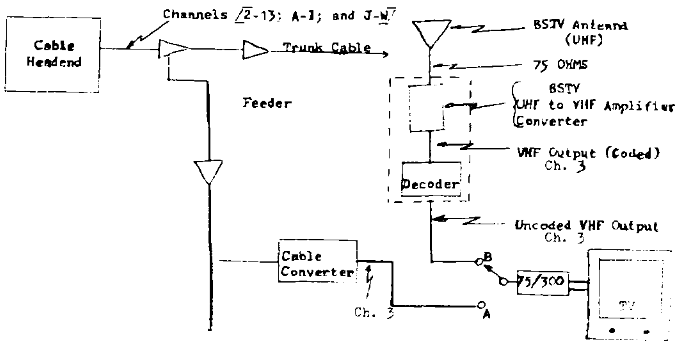

FIGURE 8

complaint from an off-air, non-cable subscriber alleges interference, it would be virtually impossible to determine which one of the systems is at fault. This further demonstrates the necessity for a service agreement between the systems. This BSTV off-air system appears to be compatible with all three types of cable systems regardless of the STV-Model system utilized by the BSTV station. However, in the M-C-S-S system a three way selector switch would have to be used with a dual cable system.

MULTIPLE BSTV STATION IN THE CABLE COMMUNITY

While the technical compatibility problems of interfacing cable with a single BSTV station are major, these problems become much more abstruse when two or more BSTV stations placing Grade B signals over the cable community may require carriage on the cable system. The Commission on December 15, 1977 adopted a Notice of Proposed Rule Making in Docket 21502 9/ in which it was stated: "Because of the significant interest presently being shown by broadcasters and the public in the operation of BSTV stations and the development of the industry since...1969, we are proposing to consider a change in the 'one-to-a-community' requirement specified in Section 73.642(a)(3)..."

Regardless of whether or not the Commission amends the "one-to-a-community" rule, cable systems may be receiving two or more BSTV stations with at least Grade A contour signals over their cable communities under the present rule. Therefore, if the Commission decides that cable systems must carry BSTV station's premium programs, additional equipment will be needed at both the cable headend and subscribers terminal. Since the premium encoding/decoding system discussed herein, as well as those already approved by the Commission, are not compatible, the subscriber terminal would have to be modified by either: (1) a decoder, whether connected to the drop cable or connected to a separate BSTV reception antenna, for each BSTV station carried on the system and requested by a subscriber; (2) traps, or (3) a new unscrambling unit would have to be developed and placed on the market replacing the present BSTV decoder as well as the cable converter. This multiple premium signal converter must be capable of receiving and decoding multiple premium program channels at the subscribers terminal. Currently, the cable converter is only capable of decoding one premium encoded channel. When other premium encoded channels are carried on the system, either: (1) a decoder is added in series with the cable converter; (2) a trap is used to weaken this extra premium signal on the non-premium subscriber receiver who is not interested in paying for and/or receiving this extra premium signal, or (3) off-air antenna(s) with the appropriated converter/decoder must be installed.

Cable systems should assume that if there is a potential market for multiple premium program channels, many of their cable subscribers may be willing to invest an additional $7.87 10/ per month above their average $7.50 per month basic cable subscription fee plus $7.87 for the premium cable program. This would involve a total monthly fee of approximately $23.24 from those cable subscribers wishing to view at least two premium programs. At this monthly rate, one would not expect to have very many multiple premium channel cable subscribers. However, if for some reason the monthly cost per premium channel starts to decline to a rate where there could be a potential market for multiple premium program channels from cable subscribers, the need for a new converter/decoder unit, capable of handling multiple premium program channels becomes more pressing. In this regard, it is noted that there presently exists a number of premium program companies 11/ attempting to make their product available to subscribers by using, in addition to cable systems, other distribution systems /e.g., Multipoint Distribution Service (MDS), 12/ Master Antenna Television (MATV)

9/ Memorandum Opinion and Order and Notice of Inquiry and Notice of Proposed Rule Making in Docket 21502, 67 FCC 2d ___, 43 F. R. 1516 (erratum 43 F. R. 2413).

10/ This fee was extracted from NCTA's Pay Cable Fact Sheet Information Bulletin. This represents a "Typical Pay Cable Rate."

11/ Some premium program suppliers are: Associated Press; Bestvision, Inc.; Broadband; Cinemerica, Inc.; Hollywood Home Theatre; Home Box Office; Optical Systems; P.R.I.S.M.; Pay TV Services; Reuters; Satoni Productions; Showtime-Viacom; Star Channel; United Press International; Warner Qube; and Home Theatre Network, Inc.

12/ MDS stations can utilize two adjacent channels in the top fifty markets. The band 2150-2156 MHz is designated Channel 1 and is available in all markets. The band 2156-2162 MHz is designated Channel 2 and is available in the top 50 markets. Therefore, it is conceivable that many cable communities within a 25-30 mile radius of the top 50 markets could be receiving at least 2 MDS stations offering different programs on each station. As of February 14, 1978 the Commission had granted 169 MDS construction permits throughout the country for Channel 1. There are approximately 360 pending construction permit applications on file; and 51 MDS stations licensed around the country.

systems, Common Carrier Satellites and Point-to-Point Microwave, and BSTV stations7/. It is conceivable that all the above distribution systems could be offering different premium programming in the cable community and some cable subscribers may request one or more additional premium channels from the abundance of premium channels available.

Presently, it appears that a major market area could have the following compliments of premium program: two, MDS stations; two, satellite premium program channels (HBO and Viacom are two of the largest national premium program suppliers using satellite); and MATV systems in large apartments, hotels and motels are presently offering premium programming.

Therefore, with little or no government interference, cable systems operating in such diverse premium programming markets, are not presently encountering any difficult compatibility/interface problems which are not being handled.

PIRACY

Piracy is the curse of any premium program subscription service. Manufacturers are constantly examining new encoding/decoding techniques for their systems to minimize piracy. Nevertheless, piracy continues to occur. It is possible for a BSTV station signal utilizing either the STV Model-1, 2 or 3 system to be pirated. However, pirating may be easier and faster on the STV Model 3 system and much more difficult to virtually impossible on the STV Model 1 and 2 systems, respectively. In any event, pirating the BSTV station's signal by breaking the code used by any of the hypothetical models would involve varying degrees of sophisticated electronic equipment. Moreover, the equipment involved would probably be beyond the means of even the most competent TV repairman. 13/ Pirating the signal is further complicated when the premium signal encoding is varied from program to program as in the STV Model -1 and 2 systems.

Unscrambling the STV Model 3 system, involves the lest knowledge of electronics and/or electrical engineering. In the STV Model 3 system, if the interference signal impressed on the normal composite video signal and the intercarrier audio signal can be duplicated, the system can be defeated.

13/ Blonder-Tongue in an information brochure entitled How to Secure Your Pay TV Investment, estimates that the technician would probably need more than $15,000 of laboratory test equipment and a masters degree in electrical engineering to unscramble an encoded audio and video system using integrated circuits.

In the STV Model-1 system, which appears to be more secure that the STV Model 3 system, more knowledge of electronics is required to defeat this system. Since this system uses an inversion of the video raster in a fixed pattern, the pattern for the entire vertical frame appears to be during the vertical sync interval and/or is keyed into the horizontal sync period. Therefore, it appears that the circuitry to duplicate the decoder can be constructed by a competent electronic/electrical engineer. If duplication of the decoder, and the coded program select ticket can take place, the Model-1 system can be defeated.

The STV Model-2 system appears to be the most secure, however, it also is more expensive. This system provides, simultaneously, features that the Model-1 and 3 systems cannot. The Model-2 system provides the following features simultaneously:

1. Scrambling via inversion of some of the horizontal scan lines, producing a fuzzy picture which is unpleasant to watch. This method is undetectable by electrical means. This is not true for the Model-1 and 3 systems.

2. Specific program control of video and audio scrambling at the station. This allows the BSTV station to "turn on" or "turn-off" a large number of subscriber's decoders every minute.

3. Two-way communication is provided by telephone lines. This allows service requests from the subscriber to travel, by telephone interface, to the BSTV station, thereby, eliminating the need to make service requests well in advance of premium program transmission.

4. The functional dependence of the decoder on the BSTV station's control signal. The absence of a command signal directed at the decoder automatically causes the decoder to become disabled. Therefore, theft of the decoder or failure to pay for service can be countered with a quick disabling of the decoder. This avoids the need to physically travel to the decoder site.

It appears that unscrambling the Model-2 system can only occur by obtaining a decoder surrepetitiously and then duplicating the command signal from the BSTV station's. However, as indicated in the beginning of this section, the BSTV premium signal can be pirated, even though the STV Model-2 system furnishes the most security. It appears that individuals who surreptitiously obtains a decoder for the Model-1 and 3 systems would have access to the unscrambled premium programming. In the Model-1 system, it is not difficult to duplicate the insert card. This form of piracy appear to be the primary way BSTV stations premium signals are being pirated. When a BSTV premium program subscriber using a STV Model-1 or 3 decoder moves from one location to another within the station's service area, and illegally takes the decoder, these decoders can easily be re-connected at the new location. Therefore, this former subscriber is now able to view the BSTV decoded premium programming without the knowledge of the BSTV station. Surreptitiously securing a STV Model-2 decoder would not automatically allow the person to view the decoded premium programming. It appears, therefore, that pirating can be virtually eliminated when the STV Model-2 system is utilized.

What problem would a mandatory carriage rule have on the cable system ability to receive a good quality BSTV station signal?

The proposed Commission rules regarding carriage of the BSTV station's signal by cable system have been directed at the station's predicted Grade B contour. As indicated in the history section of this paper, the Commission, on March 21, 1966, adopted a Further Notice of Proposed Rulemaking and Notice of Inquiry in Docket No. 11279, and invited comments on the question, *inter alia*, would the rules on carriage of signals of local stations over cable systems apply to carriage of BSTV premium programs? Moreover, in a Third Further Notice adopted on December 12, 1968, 14/ the Commission proposed that cable systems operating within a BSTV station's Grade B contour carry both the coded and uncoded programming of the BSTV station, exclusive of decoding the coded signal at the cable system headend. This Notice also invited comments on a proposed rule which stated that cable systems may not extend the BSTV station's premium programming beyond the station's Grade B contour.

The BSTV station predicted Grade B contour is simply that, a predicted contour. It is a statistical tool used by the Commission to define an area where 50 percent of the viewers, having an outdoor antenna 30 feet high, can expect satisfactory reception 90 percent of the time. The Grade B contour reveals nothing regarding the actual availability of a television station's signal in a given area. Actual field strength measurements and/or visual observation are techniques utilized by the Commission in the past to determine the actual availability and quality of a television station signal in a given area. Because of the terrain in certain areas, the Commission has been aware of situations where communities located only a few miles from television stations have been unable to receive these stations off-air signals even though the community was well within the station's predicted Grade A and B contours.

14/ Third Further Notice of Proposed Rulemaking in Docket 11279, FCC 68-1175, 15 FCC 2d 601.

In addition, there is no way, absent actual field test, to determine whether the BSTV station premium signal coverage extends as far as the non-premium signal of a BSTV station. Under Section 73.644(b)(4), the BSTV station is precluded from transmitting its premium and non-premium programs at different signal strengths. The rule states:

> The technical system shall enable stations transmitting subscription television programs to produce visual and aural signal coverage and receive program quality not significantly inferior, in the judgment of the Commission, to that produced by stations using the normal . . . transmission standards . . . without employing additional effective radiated power for either the visual and aural signals.

Moreover, the quality of the STV signal must not be degraded as referenced in Section 73.644(b)(5) as follows:

> The encoded visual and aural programs shall be recoverable without perceptible degradation as compared to the same programs transmitted in accordance with Commission monochrome and color standards.

However, with the diversity of encoding/decoding system on the market and since there are only two operating BSTV stations in the country, the Commission should probably allow ample time to elapse to assess the practical feasibility of BSTV stations' compliance with Sections 73.644(b)(4) and (5) of the Rules. Therefore, it would be **premature without additional research for the Commission to formulate rules on cable carriage of BSTV premium programming based on the station's present Grade A and B contours.**

TRANSLATOR

It is also noted that when 100 watt television translator stations are used to rebroadcast a BSTV station signal, problems regarding the formulation of mandatory carriage rules become more complex. Presently, cable systems are required to carry 100 watt translators licensed to the cable community. One problem confronting cable systems is the translator frequency tolerance. Section 74.761(a) of the Commission's Rules states that a transmitter rated at not more than 100 watts peak visual power, shall maintain the output frequency within 0.02% of the visual carrier and the aural carrier center frequencies for the assigned translator channel. This translator tolerance has been especially troublesome to cable television systems. On April 20, 1977, the Commission in the Report and Order of Docket 20765, 64 FCC 2d 743, 746 (1977) relaxed certain frequency control standards for cable systems in receiving and retransmitting TV translator signals because these signals "in some cases are not required to have such close frequency control." Responding to comments of New York and New Jersey cable regulators that translator standards ought to be tightened, Commission said "we do expect to examine the question of frequency tolerances for low power translator stations, but we believe this matter should be dealt with in a separate proceeding."

Cable systems re-transmitting television translator stations must maintain the visual carrier frequency 1.25 MHz ± 25 KHz above the lower frequency boundary of the cable television channel when the first adjacent cable channels to the channel carrying the translator are used. 15/ Because these 100 watt translator's frquency tolerance can vary as much as ± 178 KHz for Channel 83, cable operators are required to capture this ± 178 frequency tolerance signal in a ± 25 KHz window and thereafter, deliver this translator signal to the subscriber terminal with the visual carriage frequency 1.25 MHz ± 25 KHz.

Moreover, with the Commission adoption on December 8, 1977 of the Report and Order in Docket 20539, FCC 77-836, 67 FCC 2d Pamphlet 3, 43 F. R. 1943 allowing translator to use modulation when a television signal is transported to a translator by FM microwave, the quality of the BSTV station signal traveling via translator becomes a critical issue for cable systems. Each demodulation/remodulation step in a television system affects the quality of the signal. Therefore, cable systems receiving a BSTV station signal via a 100 watt translator and demodulate the translator signal at the cable headend and then remodulate the signal for distribution over the cable system, may be delivering such a poor quality BSTV premium signal that no cable subscribers would be willing to subscribe to this premium programming. These are potential problems that only experience under actual operating conditions in the marketplace can hopefully furnish answers. It does appear however, that the translator problems become less critical when the off-air cable/BSTV system depicted in Figure 8 is utilized: Provide, however, That appropriate radiation and isolation standards are formulated to interface the BSTV premium system with the cable system: And Provided further, That the service, installation and maintenance agreement problem between the systems could be addressed to minimize the number of technicians allowed to tamper with equipment at the cable subscriber terminal.

15/ However, Section 76.605(a)(2) affords some relief to cable systems when the cable: (1) signal is received by means of a translator and (2) does not carry signal on neither of the first adjacent channels in frequency to the channel on which the translator signal is carried. In this case the visual carrier frequency shall be maintained 1.25 MHz ± (25 + T) KHz above the lower frequency boundary of the cable television channel where T is the frequency tolerance in KHz allowed the television broadcast translator pursuant to 74.761 of the Rules.

Conclusion

The author has attempted to give an overview of the interfacing problems that could occur if the Commission in all its wisdom, were to require mandatory carriage of the premium programming from BSTV stations. It should be evident from this paper, that any attempt to formulate policy and/or a set of rules at this time may result in curtailing the technological developments occurring in both the BSTV premium system and the cable system markets. The author is of the opinion that it would be pre-mature without further research for the Commission to get involved at this time. With technology changing at such a rapid pace, it is not unreasonable to assume that a reasonably priced, multiple premium signal unit at the subscriber terminal could be available within a few years: Provided, however, That a market exist and that it would be in the public interest. Cable operators should monitor closely any attempt by the Commission to: (1) standardize BSTV premium systems; (2) formulate additional or modified technical standards for BSTV premium encoder/decoder systems, and (3) establish a policy and/or specific rules ragarding mandatory carriage of BSTV station premium signals over cable systems. Moreover, cable systems should also: (1) monitor attempts by new and existing operating stations to interface their premium programming with cable subscribers within their service area, (2) comment on, and furnish technical data in, any proceeding from, or submitted to the Commission regarding cable carriage of a BSTV station premium programming, and (3) assist equipment manufacturers of both encoding/decoding and cable equipment in developing a multiple premium signal unit for the cable subscriber terminal.

Note: Statements which have appeared in this paper are those of the author alone, and does not necessarily represent the position of the Federal Communications Commission.

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LINEAR LASER FOR CATV APPLICATION

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Abstract - The structure and the properties of a laser that delivers up to 7 mW per face linear optical power with respect to the current are described. The lasers are fabricated from GaAs-GaAlAs wafers grown by the liquid phase epitaxial technique. By carefully controlling the waveguide dimensions with proton implantation, we have substantially improved the linearity. The second and third harmonics are respectively less than 55 dB and 65 dB below the fundamental at 70% modulation. The signal to noise ratio is typically less than 65 dB. The laser has been used to transmit 12 channels of TV signal through a single fiber of more than 1 mile long without deterioration of the picture quality.

I. INTRODUCTION

In a conventional CATV system, the base band signal is carried by carrier waves which propagate through the cable. At the receiving end, a TV receiver demodulates the carriers and displays the information from the base band signal on the screen. In order to be competitive with this conventional system, a fiber optic CATV should be designed in such a way that minimum interfaces between the transmitter and receiver are introduced. This can be achieved by using the carriers to modulate the source light. The light is then sent through an optical fiber. A photodector at the receiving end is used to recover the signal which is subsequently fed to the conventional receiver. In effect, a light source, a piece of fiber and a photodector is used to replace the conventional coaxial cable.

This analog system will be basically simple and cost effective if two requirements are met. The first is that the carriers are faithfully recovered at the receiver for distortion free signal transmission. The second is that the light source must have a broad bandwidth 50 MHz to 250 MHz. The former requires a high degree of linearity in the light output vs. the current input of the light source. The latter requires a light source that is fast enough to respond to the modulation of the carrier frequencies. A properly designed injection laser diode can meet the above two requirements. In this paper, we describe the structure, fabrication, properties and performance of such a laser.

II. STRUCTURE OF A HIGHLY LINEAR LASER

An injection laser is a semiconductor p-n junction device which emits coherent light upon application of a forward bias. Its use as a light source for fiber optic communication is particularly suitable because of small size, high coupling efficiency, direct modulation capability and easy interface with conventional electronic circuitry. There are many different kinds of injection lasers. Among them, the stripe-geometry GaAs-GaAlAs double heterostructure lasers are the most developed and reliable devices which have been widely used since its introduction in the early 1970's. Most of the previous applications of the GaAs-GaAlAs lasers however, concerned only with using the laser as a light source; the problems associated with the linearity, and self-pulsing and relaxation oscillation which limit the bandwidth for modulation and are commonly observed in an injection laser were never considered serious. It was until a few years ago, when the lasers were used in the fiber optic area for data transmission, the problems of linearity and modulation rate started attracting wide attention. Many new structures have since been developed to improve the linearity and suppress self-pulsing and relaxation oscillation. We have developed a laser structure which possesses high degree of linearity and does not show self-pulsing and relaxation oscillation.

The structure of the laser is shown in Figure 1. The size of the laser is typically 380 μm long x 250 μm wide and 100 μm thick. It consists of four epitaxial thin crystalline layers on a GaAs substrate. The epitaxial layers are grown by the liquid phase technique. Fig. 1 shows a very thin p-type GaAs layer which is sandwiched between the two GaAlAs layers containing 24% Al. The interfaces between the GaAs layer and the two GaAlAs layers consist of two heterojunctions and hence the name double heterostructure. The two GaAlAs layers have larger energy gap than the GaAs layer. The larger energy gap produces two potential barriers at the heterojunctions. When a forward bias is applied, the positive and negative charge carriers are confined in the thin GaAs layer by the potential barriers and are forced to recombine. The emitted recombination radiation is further confined and guided in the GaAs layer because the layer has a higher refractive index than the two surrounding GaAlAs layers. Sufficient optical gain can be generated in this GaAs active layer by the interaction between the emitted protons and the charged carriers. As the forward bias increases to the point called the lasing threshold, the optical losses caused by the absorption and scattering are overcome by the optical gain. The laser oscillation can occur if a pair of mirrors is provided. In the case of semiconductor lasers, the mirrors are usually formed by a set of crystalgraphic planes and therefore no external mirrors are needed.

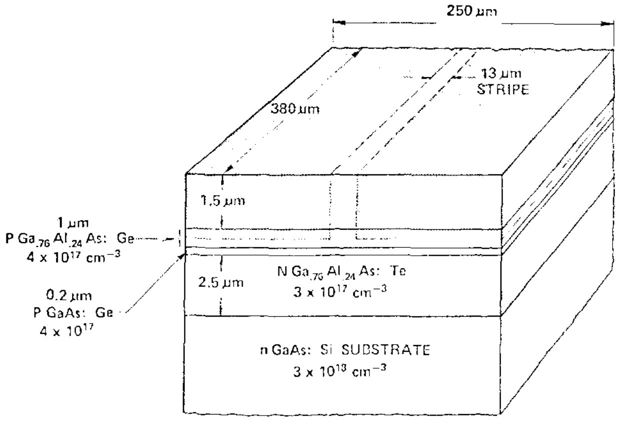

Fig. 1 Layer Structure of the Stripe-Geometry Double Heterostructure Laser.

At a typical threshold current density of $1KA/cm^2$, it requires one ampare to operated a laser with the dimensions shown in Fig. 1. Thus, even for such a small device, a very efficient heat sinking must be used in order to achieve CW operation. Futhermore, such a device generally exhibits multimodes as well as multi-lasing filaments in the plane parallel to the junction. The size of the filament is between 5 to 10 µm. The concept of a stripe-geometry laser is based on the idea that by forming a stripe contact of the size of a filament, one should excite only one filament. In addition, the total current required to operate the laser is greatly reduced and thus is favorable for CW operation without using an elaborate heat sink. The waveguide dimensions in this case is thus defined by the two heterojunctions in the vertical direction and by the current spread in the active layer in the horizontal direction. Because of the dimensional asymmentry and difference in waveguiding mechanisms in both directions, the light pattern diverges 45° vertically and 10° horizontally.

III. PROPERTIES OF A HIGHLY LINEAR LASER

The light output vs. current input characteristics is shown in Fig. 2(a). The light intensity increases very slowly initially. As the current increases beyond the threshold of the laser, the light intensity increases very rapidly. The degree of linearity of the laser is determined by the behavior of the light output with the input current in this range. If the waveguide dimensions are not stable with respect ot the current variation, poor linearity results. In the extreme case, a kink in the output as shown in Fig. 2(b) is observed This nonlinearity is unacceptable in the CATV system.

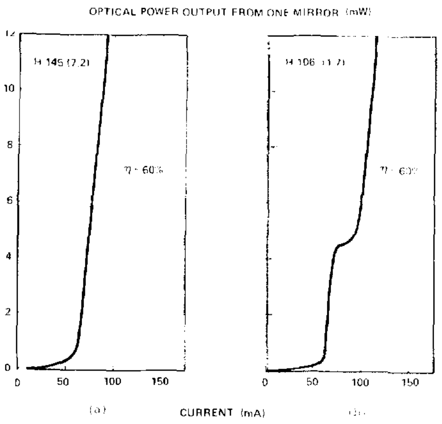

Fig. 2 Output Characteristics of Linear and "Kinked" Lasers.

In most of the commercially available lasers, the stripe contact is formed by cutting a stripe opening on an insulating layer deposited on the surface. Because of the finite distance of the active layer from the surface, the current spreads substantially by the time it reaches the active layer. Since the extent of the current spread depends on the current, the lateral waveguide dimension also changes with current. This type of laser, although is simple to make, often shows poor linearity as well as poor transverse mode stability. On the other hand, our laser uses proton implantation to define the stripe. The implanted region as shown by the shaded region in Fig. 1 turns into semi-insulating and hence only the stipe region can conduct current. Furthermore, the current spread can be controlled by the implantation depth. If the implantation depth is equal to the distance of the active layer from the surface, the current spread in the active layer is greatly minimized. Consequently, we have a much better defined waveguide with respect to the current variation and hence the superior linearity and more stable transverse mode structure.

For analog modulation, a constant current greater than the threshold value is used to bias the laser. The TV carrier shgnals are superimposed to produce the modulation. The bias current and modulation depth are then adjusted to obtain minimum distortion and maximum signal to noise ratio. It is important to point out, however, that distortion can still be introduced by operating the laser improperly even though the laser is perfectly linear. As is common to all light emitting devices, the laser properties are sensitive to the temperature variation. The temperature variation causes the threshold current to change which in turn shifts the curves in Fig. 2 horizontally. The shape of the curves remain unchanged. Thus, for a constant bias current, the bias power can fluctuate in an fluctuating ambient. This can cause an apparent nonlinearity in the light output vs. current input characteristics.

It is, therefore, required to develop some means to stabilize the bias point for distortion free transmission. We have designed a feedback curcuit which is capable of keeping the laser operating at a constant output power. A photodector placed near one of the mirrors is used to detect the laser light. The signal from the photodector is amplified and fed into the base circuit of a transistor to control the collector current which passes through the laser. The rf modulation signal can be applied directly to the laser through some appropriate impedance match network. Because the slope of the light output vs. input current (Fig. 2(a)) is quite steep, only a small input signal is required to obtain relatively deep modulation. For example, a 0.75 volt peak to peak rf signal can produce more than 70% modulation when the laser is in series with a 70Ω resistor and is directly connected to a 75Ω input source. An even smaller voltage can be used if an appropriate impedance match network is used. Fig. 3 shows an optical transmitter designed for transmitting 12 channels of TV signals through a single fiber. A transformer was used to match the 75Ω system to an 18Ω input. It also incorporated a thermal electric cooler which ensures the operation of the laser at 25°C even the ambient temperature gets as high as 70°C.

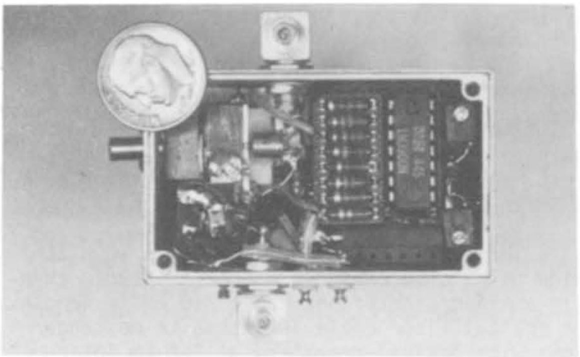

Fig. 3 A CATV Optical Transmitter.

The frequency response of the package is essentially flat from 10 MHz to 280 MHz. In this frequency range, second and third harmonics are typically less than 55 dB and 65 dB respectively below the fundamental at 70% modulation when the laser is biased at 3 mW. For a 12 channel input, the bias point and modulation depth were adjusted to give maximum signal to noise ratio and minimum cross modulation. A signal to noise ratio of less than 65 dB with cross modulation of less than 60 dB was obtained. The transmitter was used to transmit 12 channels of TV signal directly from an antenna through 1 mile of optical fiber without any visible distortion.

IV. CONCLUSION

Because of its large bandwidth, the injection laser is suitable as a light source for fiber optic CATV application. The simplest and most economical CATV system, however, demands high degree of linearity on the light output characteristics of the laser. We have been able to make such high quality lasers by properly controlling the waveguide structure of our laser.

LOW COST CARS BAND MICROWAVE SYSTEMS

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ABSTRACT

This paper summarizes the efforts expended by Microwave Associates, Inc. during the past year resulting in the design and placing into production a line of compact CARS band FM microwave receivers and transmitters using cost effective techniques borrowed from those used by the Company in mass producing microwave Gunn diode RF powered transceivers for the police radar and intrusion alarm markets. The compact new CARS band units, produced at a fraction of the cost of traditional designs, also rely heavily on the latest linear and digital integrated circuits which have appeared on the market during the past two years. The paper covers both digital and analogue methods of stabilizing Gunn diode oscillators that are compatible with high quality video modulation. The authors also discuss both the technical and cost considerations of systems interfacing with TVRO terminals and CATV head ends incorporating these new designs.

BACKGROUND

Traditionally, CATV operators have been using microwaves to import channels from other areas by locating a directional TV antenna at some strategic high point, and bringing in its received signals by as many as five hops of either private or common carrier microwave to the cable head end. This particular use of microwaves remains important but it is also now possible to bring in channels considered high quality from both a technical and entertainment point of view via a satellite receive-only terminal for a relatively modest investment. It is estimated that there are as many as 200 such terminals in operation today.

TODAY'S CATV SYSTEMS

The typical 1978 CATV network may well be a hybrid one combining perhaps four imported channels using up to two hops of microwave such as the low cost units to be described in this paper, a TVRO terminal located in a site which may or may not use some low cost microwave to transport say three satellite-receive channels to the operator's head end and possibly up to two hops to couple the TVRO output to other head ends either owned by the operator or cost-shared by operators in readily accessible adjacent towns. Figure (1) is one possible arrangement. The typical 1978 network will also have up to three channels involving local origin of some sort. For all the above uses, the selection of microwave vs. cable vs.

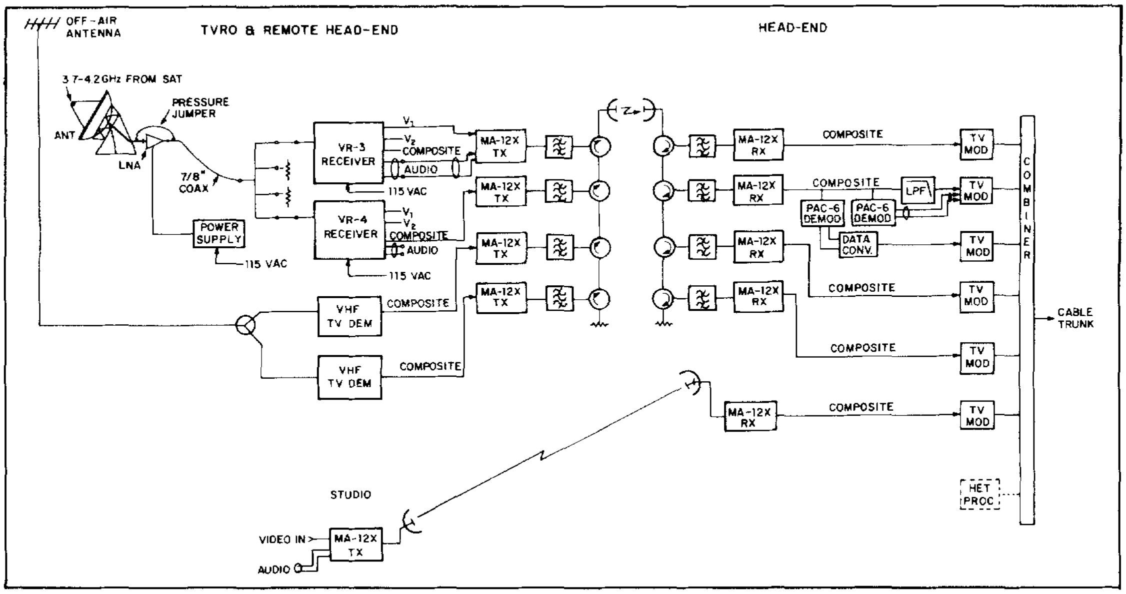


FIGURE 1. A TYPICAL 1978 CATV NETWORK

common carrier will be particularly sensitive to the cost trade-offs involved. If lakes, rivers, expensive real estate, or any area with a high political/red tape content must be bridged, the low cost microwave system will probably win out. Cables over short distances, where a large number of channels are involved, will probably be the method of choice in flat farmland or its equivalent.

In recent years, amplitude-modulated microwaves have been used extensively with systems involving up to 40 channels. Systems with fewer channel requirements such as found in rural areas are generally attracted to the low cost FM systems described in this paper. FM systems also offer an advantage in regions of frequent heavy rainfall, purely due to the greater fade margins.

LOW COST MICROWAVE DEFINED

The authors have chosen to identify the term "low cost microwave"(1)(2) with the rather large grouping of commercial microwave components and subsystems which have mushroomed in volume in the past five years and are generally associated with police radar, intrusion alarms, sensors for door openers, etc. All of these subsystems have one common technology in that they rely on the use of one or more small gallium arsenide Gunn diodes. J. B. Gunn, a member of the IBM technical staff, invented the diode that bears his name in the middle sixties. This tiny device has the property that when mounted in a small resonant cavity and powered by approximately 10 volts of DC, the DC is converted directly into useful readily modulated microwave energy. For several years, these Gunn diode oscillators have been also used as local oscillators in microwave super-heterodyne receivers in more sophisticated systems. Their use in communications systems up until a year ago has been somewhat limited due to their general tendency to drift downward in frequency with increase in temperature, thus requiring an oven for stable performance.

THE TRANSMITTER

During the past year, economical phase-locked Gunn oscillator circuits have been developed. Figure (2) shows a cutaway of a Gunn oscillator from an MA-12XC transmitter suitable for FM video modulation. Using cheap external circuits, this unit can be phase-locked to a crystal to achieve stability over wide temperature ranges.

As can be seen, the cutaway shows three separate resonant cavities interconnected by variable iris couplers. The left hand cavity with a large flange contains the basic Gunn oscillator and a gallium arsenide tuning varactor accessible electrically from both sides. All interconnections to the diodes are through cylindrical RF chokes with the ability to pass DC and modulating voltage but presenting a high impedance, hence isolation to microwave energy. The small white ceramic cylinders seen in the upper portion of the left and right hand cavities are

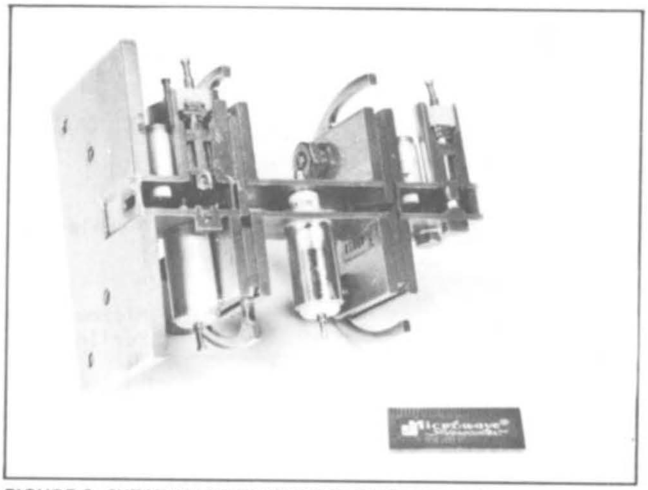


FIGURE 2. CUTAWAY OF 12XC GUNN OSCILLATOR/ AFC ASSEMBLY

used for mechanical tuning. In this unit, while most of the oscillator energy is coupled to the load (antenna) through the flange/iris combination on the extreme left, the smaller iris in the back of the oscillator cavity feeds a fraction of the energy to a Schottky mixer diode in the center cavity. The third cavity on the right hand containing a multiplier-type varactor diode is coupled to the right hand end of the mixer cavity. This varactor diode is driven by approximately 15 milliwatts at 200 MHz. The 200 MHz is generated by 100 MHz overtone crystal oscillator which drives a transistor doubler. When this 200 MHz energy impacts the varactor, a spectrum of microwave energy is generated with comb lines separated by 200 MHz. The oscillator cavity is mechanically adjusted to provide a signal which, say 12.75 GHz, when mixed with one of these lines, for instance 12.8 GHz, produces heterodyne signal at approximately 50 MHz. This 50 MHz signal passes through a limiter-preamplifier and then is divided down to 6.5 KHz by several very economical integrated circuit divider circuits. Similarly, an 8 MHz "reference" crystal is subdivided to 6.5 KHz. The two 6.5 KHz signals are then applied to a low cost IC which performs as a phase comparator. The DC error output of the comparator is fed back to the gallium arsenide tuning varactor in the Gunn diode oscillator which varies the VCO frequency until the oscillator "locks up" at 12.75 GHz. The low comparison frequency has been selected to allow the tuning varactor to receive simultaneously video modulation, the AFC error voltage and an adjustable DC voltage for manually tuning the oscillator. This phase-locking technique, standard for years at lower frequencies, can now be accomplished at microwaves since all of the components used have been produced in large quantities to serve other non-microwave markets thus greatly decreasing their cost even before applying the incremental volume leverage which must accrue when more of these oscillators are used in microwave communications systems and for CATV.

The frequency stability in the 12.7 - 12.95 GHz region using the phase-locking technique described, provides better than $\pm$.005% frequency stability. The stability is primarily a function of the drift with temperature of the reference crystal and the 100 MHz overtone crystal used in the multiplier driver. Without subjecting the audience to all the technical details, Microwave Associates is now developing techniques which will greatly decrease the inherent temperature drift by introducing into the cavity materials with compensating properties. Further, a new family of hyperabrupt, low loss gallium arsenide tuning varactors is in the advanced stage of development which will greatly increase the linearity of these oscillators under modulation even when subjected to the type of temperature excursions experienced in outdoor mounting of the transmitter.

Figure (3) is a block diagram of the current production model MA-12XC transmitter. In addition to showing schematically information just described, it shows how the output of the oscillator is coupled through an isolator/filter combination to the antenna feed providing a minimum output of +13 dBm. The digital AFC/video block illustrates the interconnections with the AFC module. The unit is powered by 110 V 60 Hz supply consuming approximately 30 watts of power providing +18 V, +9.5 V and +5 V DC for the operating circuits. This particular block shows video with 525 line pre-emphasis. The MA-12EU model operates on 220 V/ 50 Hz mains and provides pre-emphasis for the European 625 line system. The video modulating amplifier uses readily available linear ICs. There is an optional input for 600 ohm balanced audio to provide 4.5 MHz aural subcarrier with the same modulation characteristics as broadcast TV plant. Other subcarrier frequency options are also available with the flexibility of operation with the new MA PAC-6 subcarrier demodulator.

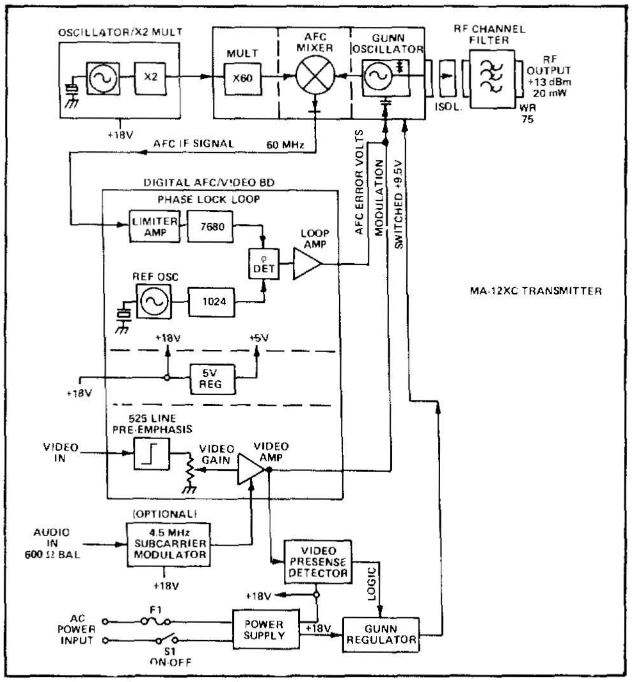


FIGURE 3

In the past, the cable operator has always brought in TV signals formatted in NTSC vestigial sideband AM with FM audio and was only faced with the problem of converting the received AM channel to the desired AM cable channel; however, today's FM satellite signals present a different problem. Here the satellite receiver such as the low cost VR-3 and VR-4 demodulates the FM microwave carrier and provides either a composite base band or separate video and audio outputs. Composite base band in this case is a combination of the standard video signal plus a 6.8 MHz FM subcarrier which is carrying the audio program information as opposed to the traditional 4.5 MHz subcarrier. When interfacing with a standard TV cable modulator, the separate audio and video outputs from the microwave receiver should be used. When interfacing with a FM microwave terrestrial link, then the composite output from the satellite receiver may be fed directly into the microwave transmitter, provided that video and audio components are separated at the FM receiver terminal before they are fed to the cable modulator.

A video presence detector with automatic transmitter turn-off is also included to meet FCC regulations. The MA-12XC has been type-accepted for CARS band and other uses. This small compact transmitter, shown in Figure (4), designed to sell at one third the price of other Microwave Associates CARS band transmitters, should be considered as a real alternative to cable or the use of common carrier services.

FIGURE 4

THE RECEIVER

Figure (5) shows the block diagram of the low cost 12XC CARS band receiver which has had wide market acceptance. Referring to the left upper side of the block diagram, the microwave signal from the antenna is connected by waveguide to the receiver mixer-VCO module via a bandpass filter/ ferrite isolator combination. For most U.S. CATV systems, the RF pass band is 25 MHz. The mixer-VCO assembly is similar in construction to the cutaway of the RF assembly shown for the 12XC transmitter but is less complex since two rather than three cavities are involved. The received signal is mixed in a Schottky diode operated at approximately 1 milliwatt of energy derived through a variable iris at the rear of the mixer from the Gunn VCO. The VCO is mechanically tuned

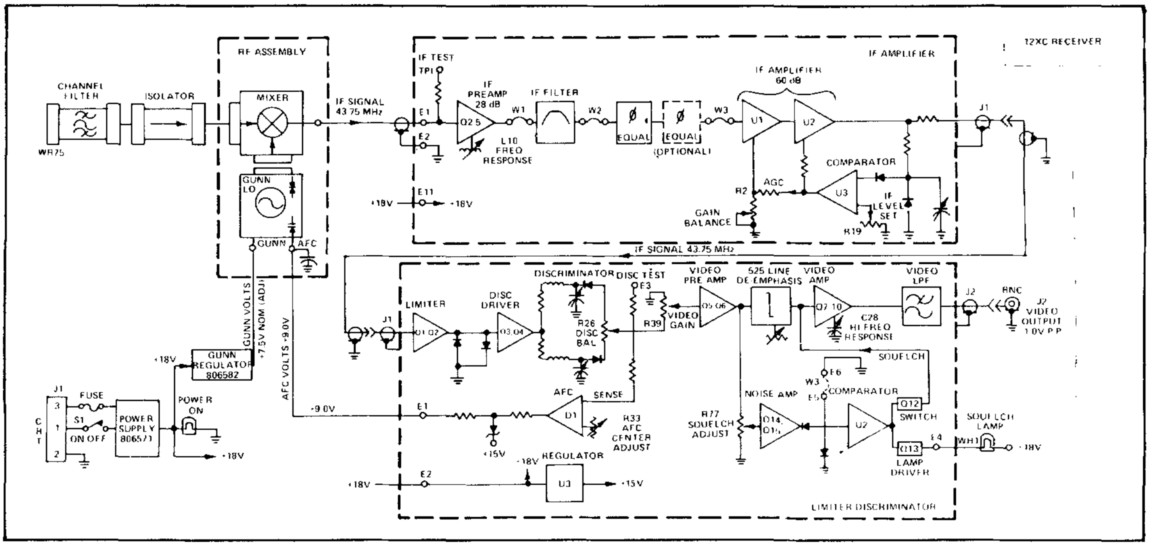


FIGURE 5

to provide an IF output from the mixer at 43.75 MHz. The intermediate frequency of 43.75 MHz is compatible both to the current availability of very low cost IC linear amplifiers (which become more expensive at higher frequencies) and with the elimination of possible "birdies" which could occur when multiple 12XC receivers are interconnected together by branching networks. The IF signal is coupled to the IF amplifier module through a low noise FET preamplifier. In the IF module, the IF signal is shaped by an IF filter which defines the noise bandwidth and provides additional adjacent channel rejection, then undergoes at least one stage of group delay equalization before entering 2 stages of IF IC amplification providing 60 dB of gain, controlled by a comparator/AGC IC.

The output of the IF amplifier is fed to the limiter/discriminator module. Here, two stages of hard limiting are provided which drive a discriminator which demodulates the FM signal and provides a base band output. Either 525 or 625 line de-emphasis and a compatible band pass filter are provided as part of the IF amplifier assembly.

Because of the inherent stability of the transmitter, the receiver needs only to provide a simple analogue AFC which is derived from the discriminator output passed through a DC amplifier to the tuning varactor in the VCO assembly. This module also contains the necessary circuitry to squelch the receiver output if no carrier is present. The receiver can be powered by either 110 V AC 60 Hz, or in the case of the 12EU, 220 V 50 Hz. Regulators provide +18 V DC and adjustable 7.5 V DC. The AFC bus operates at +9 V DC.

The 12XC transmitters and receivers were initially offered in compact cast aluminum housings, 8" x 4.5" x 4.7", weighing 6 lbs., shown in Figure (4). Although this package format meets the requirements of many users, we are also planning to offer a radio for the CARS and certain other markets packaged for rack mounting as shown in Figure (6). This arrangement will provide additional accessory circuit flexibility.

The 12XC receiver provides high quality reliable video when used to receive any video modulated stable FM microwave transmitter tuned to the proper frequency. Although many MA-12XC receivers have been sold paired with MA-12XC transmitters, considerably more have been delivered into systems using other transmitters, often in place, both of our own and other companies' manufacture. Frequently, the paths are such that higher power than the 12XC's +13 dBm is required. In this case, the 12XC receiver is often used in systems which rely on the +28 dBm output MA-12G as a primary transmitter source. The CATV operator should always consider the 12XC receiver and transmitter, each for their individual merits, rather than only as a paired 12XC system. It should be noted that as currently manufactured, the MA-12XC receiver provides only a composite video output. Video base band and audio outputs are not provided, hence the interfacing cable modulator must be capable of accepting composite video.

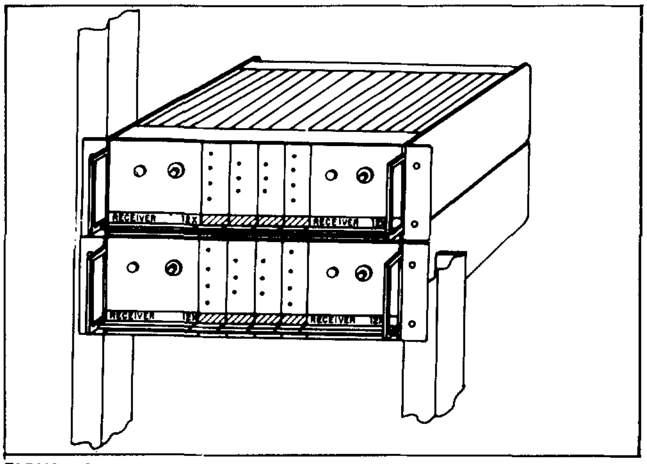


FIGURE 6

SYSTEM ARRANGEMENT

As stated before, this product was launched for the CARS band market and obviously it must provide cost and space effective support for up to twenty channels, as that is the limit under Part 78 of the FCC rules as they apply to FM service. The modular design of the 12XC offered an opportunity to equip 20 go (or return) channels in a single 7'6" (44 unit) rack and still have a few inches to spare. Figure (7) is a photograph of a typical 6-channel receiver rack-up. Figure (8) shows the general arrangement for 20-channel terminals.

Since in the 20 channel (K) Plan both vertical and horizontal polarizations are employed, a convenient and economical branching system was adopted with the upper and lower half of the rack disposed to a common polarization. The problem of combining adjacent off (or even) channels with their 25 MHz separation was solved with hybrid couplers at a slight loss penalty. However, this was offset by lower branching filter losses, with negligible adjacent channel group delay (hence differential phase) contribution. The conventional 3 port circulator combining method was used with waveguide low pass filters in each bus bar (for the ultimate protection against wandering harmonic power). With this arrangement radio equipment can be installed, new channels added, maintenance spares lit up without any on-line "tweeking" for system performance. This is an essential merit for a product of this type, since rarely will the user be equipped with sophisticated microwave line maintenance equipment.

To minimize the system-gain losses, equipment branching position assignments are "flipped" for transmitters and receivers. Figure (9) shows one polarization of a 20 channel hop. Lowest channel transmitters are positioned closest to the antenna port and the mating receiver is the furthest. The worst case total component losses for transmitter and receiver branching add up to 7.4 dB for a 4 channel assembly and 9.8 dB for a 20 channel assembly, all in K Plan. Of course, an additional transmitter rack output port is available for a "free split".

In the CARS band with precipitation effects, the name of the game is fade margin to assure system availability. With the advent of such real time revenue bearers as HBO, repeated circuit outages in the rain belt routes must be avoided. Fade margins of 40 dB (or more) are possible with a complete 12XC system. Recalling the work of Hathaway and Evans, that would set the range of path lengths from about 15 miles in the Mississippi Delta area to about 40 miles in the "L" shaped line joining San Francisco and Montana for a seven hour annual accrued outage. I'm sure we're all familiar with the curves in the Lenkurt Manual[3]

What does this mean as to outside plant with the 12XC? Figure (10) shows a handy fade margin - distance guide for a four channel system,

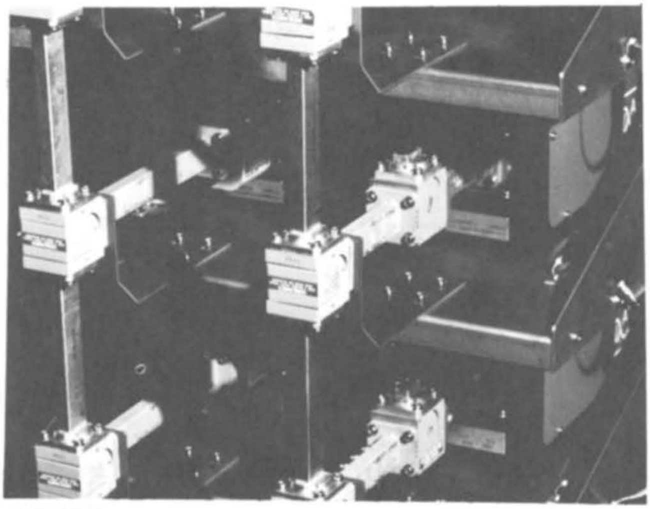
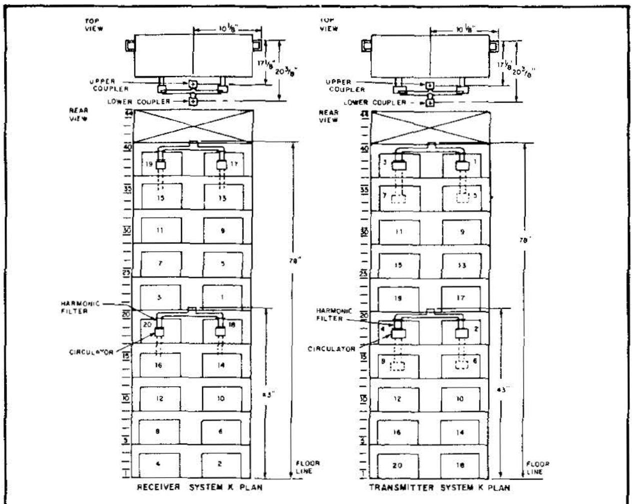


FIGURE 7



MULTICHANNEL 12XC RACK ELEVATION

FIGURE 8

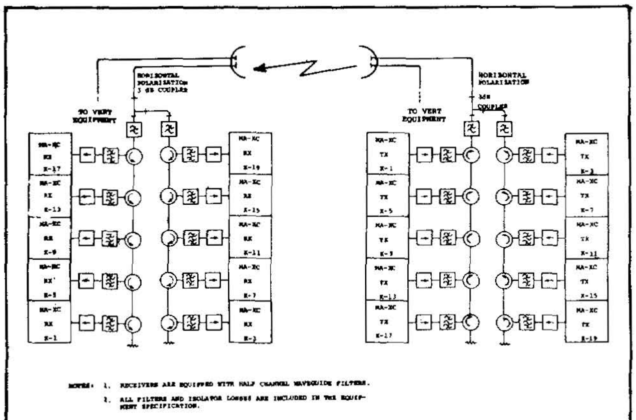

MA-XC 20 CHANNEL "K" PLAN BRANCHING CONFIGURATION

FIGURE 9

and that a pair of 10' dishes will support the 40 dB objective at about 8 miles. Considering that the 12XC receiver sells for about one third the price of conventional receivers, it is only an elementary lesson in economics to consider longer paths, and/or smaller dishes with higher power M/A transmitters (or somebody else's, as the 12XC receiver is a very good listener). Just shift the curves vertically by about 13 dB...or expect 40 dB margin at 25 miles with 10-foot dishes.

The MA-12XC system performance is shown in summary in Figure (11). This clearly indicates that the 12XC system certainly offers a very cost effective solution to many of the CATV operators' microwave problems.

References:

1. "Solid-State Microwave RF Generators"- Ham Radio Magazine, April 1977.
2. "Microwaves for the Masses" - Harlan Howe, Jr. Microwave Systems News, August 1977
3. "Engineering Considerations for Microwave Communications Systems" - GTE Lenkurt Incorporated.

BACK-TO-BACK PERFORMANCE ASSUMING STANDARD CCIR WEIGHTING, A RECEIVER CARRIER LEVEL OF −40 dBm, AND USING 525 LINE TV EMPHASIS

Video Signal-to-Noise P-P to RMS, 4 KHz to 4.5 MHz	55 dB, Minimum
Video Signal-to-Hum P-P to RMS, 10 Hz to 10 KHz	55 dB, Minimum
Differential Gain, 10/50/90% APL	1 dB, Maximum
Differential Phase, 10/50/90% APL	3°, Maximum
2T Pulse "K" Factor	2%, Maximum
Video Frequency Response, 10 KHz to 4.2 MHz	±5 IRE Units
Field Squarewave	3 IRE Units, Maximum
Luminance Chrominance Gain Inequality	6%, Maximum
Luminance Chrominance Phase Inequality	50 ns, Maximum

FIGURE 11. 12XC SYSTEM SPECIFICATIONS

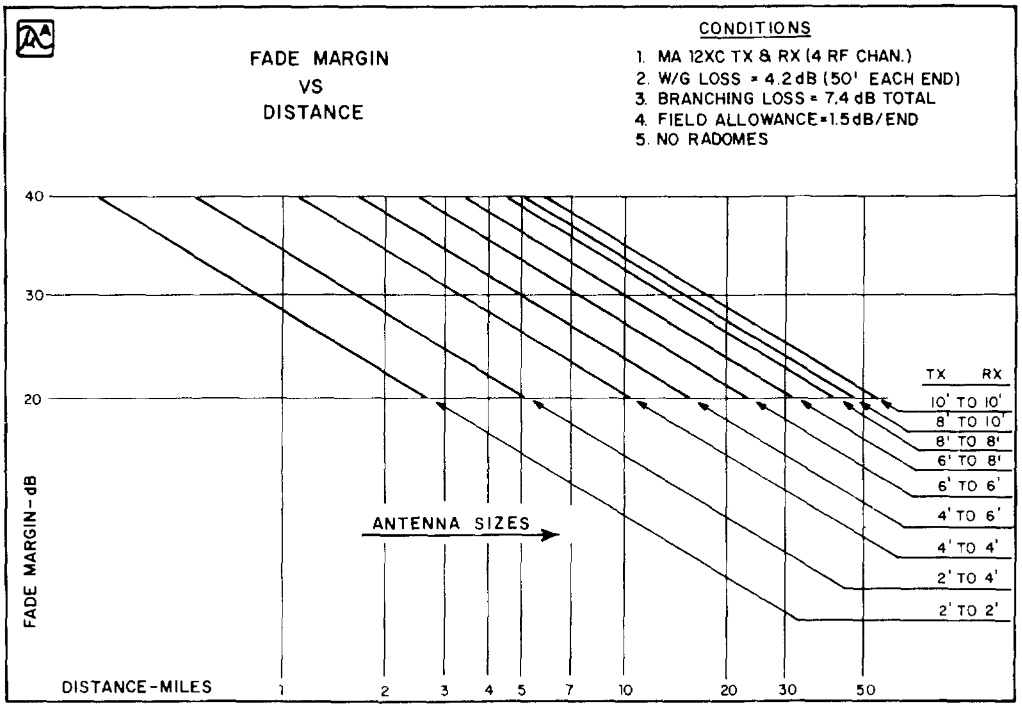


FIGURE 10

MICROPROCESSOR FOR CATV SYSTEMS

E.O. Tunmann and J.F. Roche

Tele-Engineering Corp.

ABSTRACT

The advent of microprocessor techniques has provided a means of flexible and economic automated control of switching functions.

A programmable switching unit has been developed by Tele-Engineering Corp. which permits an operator to implement a switching program which will control 16 switching functions in 196 time slots.

The system is so designed that programming is accomplished with simple techniques which can be mastered with about one hour of instruction.

The versatility of application of the system permits it to be used simultaneously for network protection, program selection and local origination programming.

This paper describes the unit, how it is programmed, and results in operational environments.

1. Introduction

Recent advances in microprocessors have resulted in the feasibility of performing operations associated with CATV systems by using such devices. The attractive feature is that many functions can be done automatically without having to have a large amount of expensive and complex equipment. This paper describes a device that was tailored to meet specific requirements existing in CATV systems.

Switching problems were analyzed to provide the necessary inputs to the design of the microprocessor as indicated in section 2.

Possible approaches to the solution of switching problems were evaluated. The advantage of the use of multiprocessors for these real time applications are discussed in section 3.

Specific ways in which the microprocessor could be used effectively were evaluated as shown in section 4.

In section 5 a detailed description is provided of a microprocessor to accomplish certain switching functions.

The operational procedures and methods of programming to accomplish specific functions is contained in section 6.

2. Switching Requirements

CATV systems have evolved to the point that switching requirements are an essential and sometimes complex aspect of system operations. Selection of a channel for distribution from a number of available off-air signals on a scheduled basis is a major source of need for suitable switching techniques. The increased use of satellite transmissions with more programs being carried on a single satellite results in requirements for preprogrammed switching between channels at the earth station receiver.

Local origination programming and remote pickup involves switching at IF or video.

The more vigorous enforcement of requirements for network nonduplication and program exclusivity mandates are other areas which impact on the need for improved switching techniques.

For many years most switching requirements could be satisfied by making personnel available, at the appropriate times, who would manually operate either IF or video switches, or in some cases change connections on a terminal board. As the requirements increased, however, it was found that personnel would have to be on-call for periods well beyond their normal work schedule to effect required switching.

The changes of programming from day to day and week to week required constant changes in the switching that was required. Satisfactory switching could be brought about only if a detailed schedule was established in advance and appropriate assignment of responsibility for specific actions be made sufficiently in advance to assure switching was accomplished. Along with advanced scheduling some mechanism had to be developed to accommodate scheduling changes.

3. Digital Techniques

In view of the above consideration, application of digital techniques were considered to be a feasible solution for switching.

There are two possible approaches to

digital application, one using mini-computers and the other using microprocessors. The minicomputer involves a memory, input and output devices, a software package and interface devices. Although hardware costs have been steadily decreasing, the software costs have remained steady, thereby causing the basic software cost to be a significant factor in the implementation of a digital system. In addition, programmers must be made available on a continuous basis.

With recent development of integrated circuits and memory chips microprocessors become a feasible method to perform intricate functions. The processor consists of a memory, input/output devices, interface devices and program logic units. The basic function to be performed are designed into the unit with allowable ranges of values to be inserted. The programming then becomes a simple operation which can be mastered after a few hours of instruction. The design of the processor can provide for adaption to a wide variety of interface devices with a minimum of restrictions.

4. Switching application

There are a wide variety of applications in which the microprocessor can be an effective device. One application involves the selection from various satellite signals on a preprogrammed basis. For example, HBO/Channel 17/ and HBO delayed are all transmitted from the same satellite in addition to PTL/TRINITY/ and Christian Broadcasting. Selection of programs from these sources with the use of a switch can add to the variety of pay and religious programs that can be offered without a substantial additional investment in hardware.

When there are more off-air signals available than the system can distribute with its hardware complement selection of best programs can be accomplished with the microprocessor consistent with the carriage allowed by FCC.

The processor will also allow the switching in of independent stations after midnight.

Local origination involves switching at video. The use of the microprocessor will allow automatic selection from a number of sources on a scheduled basis.

In case of a multihub system different programs may be distributed to various parts of the system. Use of the microprocessor would provide the necessary switching function to accomplish this flexibility in offering programs.

5. Programmable Switcher

A processor has been developed which provides programmable switching functions for the applications cited above. A functional block diagram is shown in Fig. 1. All inputs to the memory are made through a 12 button keyboard. The memory is an 8K com-

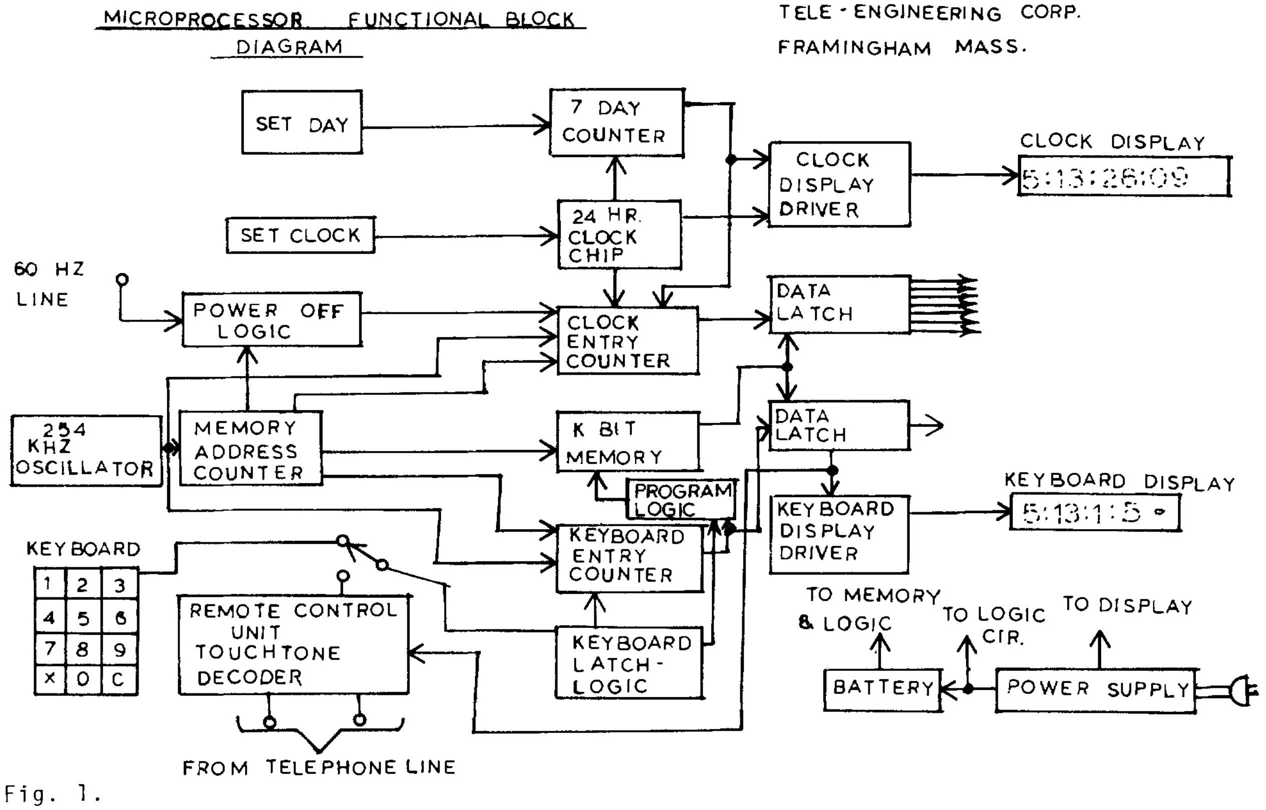


Fig. 1.

ponent and accepts all program information. The unit is designed to perform all required functions at the beginning half-hour time slots (48 per day, 7 days per week) and of carrying out 16 command functions for each time slot. The clock is set by external control for day, hour, minute and second. LED display are used to indicate the running time and a time slot that is addressed. The clock entry provides logic for activation of relay closures through a data latch. A key switch is provided which prevents the changes in the memory unless activated. When the unit is set to remote access is accomplished through a security unit and then program changes can be effected by operation of a touch tone telephone set.

The design of the unit is modular with each of the major components manufactured on its own printed circuit board. Each of the functions are accomplished by the hardware configuration of the corresponding PC board. The interconnection of the board is illustrated in Fig. 2.

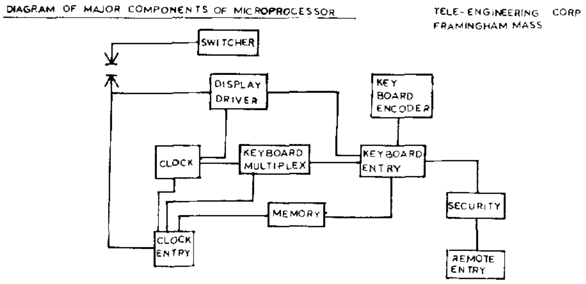


Fig. 2

Instructions are entered either locally using keyboard or remotely. The output of the keyboard entry is displayed and fed to memory. The clock provides the pulses that activate commands through the logic contained on the clock entry board. The display and driver supply appropriate level to activate LED. The remote control board decodes tones and converts them into appropriate signals for the keyboard entry. The security board denies access until cleared with the proper security code signal.

The complexity of a typical board is illustrated by Fig. 3 which indicates the component layout of the memory board. The two components identified by slanted cross-hatching are the memory element. A total of eight other integrated circuits of the CMOS type are included on this board. The boards are mounted vertically in the chassis and held in place as illustrated in Fig. 4. This arrangement of PC boards facilitates maintenance and repair

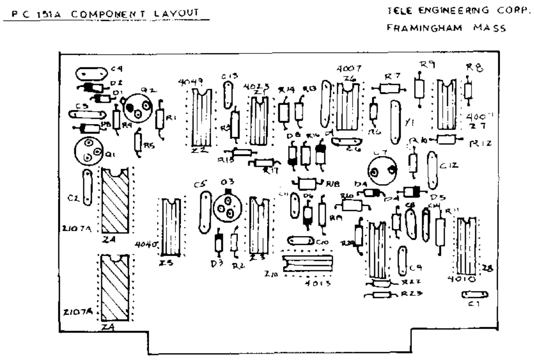


Fig. 3

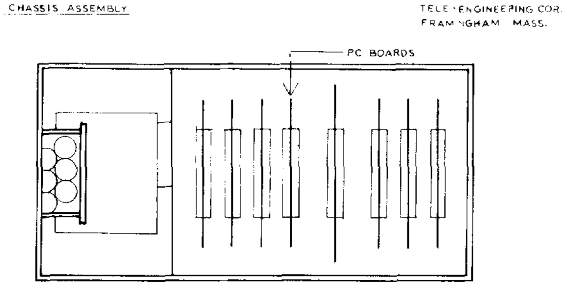


Fig. 4

A photograph of the microprocessor is shown in Fig. 5. The unit which can be rack-mounted in a standard 19" rack has a height of 5". All inputs are accomplished by action of the keyboard. Setting the clock is controlled by the first row of keyboard buttons when the "set" lock switch is turned on to set. The other key switch controls access to the memory from either local or remote station. Programs are entered with the keyboard when the key position is on local.

6. Operation and Programming

After the unit is installed, the first step in operation is to set the clock to correspond to the correct day of the week and the exact time.

"Run/Set" switch is set to "set". The clock is set to the proper date and time by use of buttons "1","4","7", and "8" of the keyboard. To set "day", button "1" is depressed until the proper day appears in the appropriate location of the clock display.

Hour and coarse minute set is accomplished by depressing "fast" set and depressing button "4" of the keyboard. When the time in the display approaches within 10 minutes of the correct time, the Button "4" is released. The slow set is then

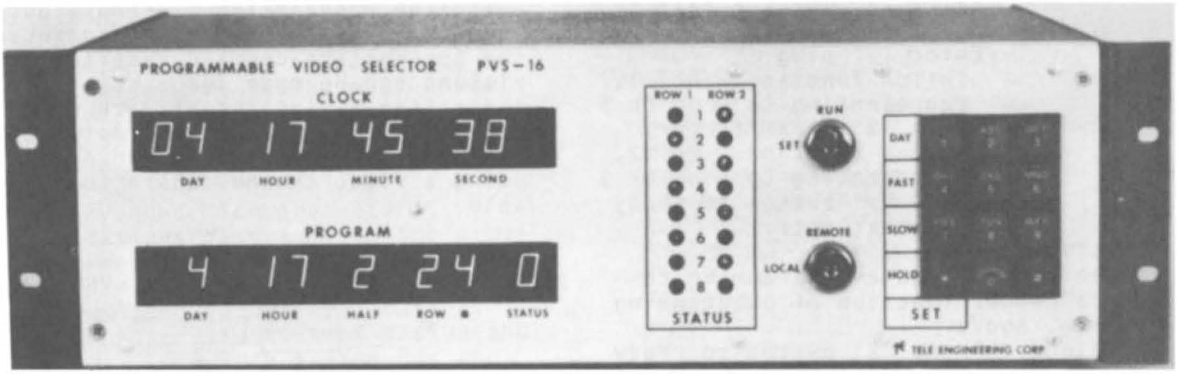


Fig. 5

used to set the nearest minutes and second. This is accomplished by depressing button "7". If time is "overshot", depress "*" button to hold clock until the actual time coincides with the displayed time. Once the time has been set, the run/set switch is turned to the run position.

Programming can be done either locally or from a remote location. When programming the unit locally, set program switch on local position. For initial operation, first clear memory by operating "clear" button in the rear of the unit. The unit is now ready for programming by time slots. An entry has to be made for any time slot in which a switching action is required. The first step for programming is to clear the display by depressing the "#" button. The following sequence is used to program a given time slot for a 2-position switch:

Day of the week - use button "1"-"7"
Hour of the day - use "00"-"23"
Half Hour - use "1" for 1st half hour
use "2" for 2nd half hour
Switch Position
Row - 1 or 2
Number - "1"- "8"
Switch Condition - use "*" for on
use "0" for off

When a matrix switch is used, it is programmed by a combination of inputs. Appropriate function numbers and status indicators must be entered 3 successive times for a given position of the switch to be activated. The built-in logic prevents two incoming channels from being simultaneously switched to the same output in the event of an error in programming.

This procedure, beginning with clearing display, is repeated for each half-hour increment. After the unit has been programmed, the lock switch is turned to remote and the program cannot be changed locally.

If a change is to be made, the following procedure is used:

Set Remote Local Switch to "local".
Enter day, hour, half-hour and switch which is to be changed.
Activate or deactivate by pressing "*" or "0".
Return switch to remote.

For remote operations the "Remote - local" switch is set on "remote". Telephone number of line to which programmer is connected is dialed. After connection is made, the unit is signalled with a two-digit security code from a touch-tone instrument. If code is correct, steady tone will be heard. Time and switch which is to be addressed is entered in the same manner as in local mode.

If for this time slot, the switch is programmed "on", signal will be grouped as follows: - - - -   - - - -   - - - - If switch is programmed "off", signal will be: - - - - - - - - - - - - -.

OPERATIONAL EXAMPLE

Switching Function Selection

A Programmable Video Selector has been installed to provide switching for
channel 5 on channel 6
" 5 on " 9
" 5 on " 6 and 9
" 4 on " 10
" 7 on " 12.

The switch functions of the IF switching unit have been selected as follows:
Switch 1 represents Ch 5 on Ch 6
" 2 " Ch 5 on Ch 9
" 3 " Ch 4 on Ch 10
" 4 " Ch 7 on Ch 12.

Operational Routines - Local Mode
(a) Programming
Problem: On Monday Ch 5 shall be carried on Ch 6 and Ch 9 from 6:30 pm to 7:00 pm
Execution: -Press "#" button to ready

for entry
- -Enter "1" for Monday
- -Enter "18" for 6:00 pm
- -Enter "2" for 2nd half hr.
- -Enter "1" for Row 1
- -Enter "1" plus "*" for switch function - No. 1, representing Ch 5 on Ch 6
- -Enter "2" plus "*" for switch function - No. 2, representing Ch 5 on Ch 9
- -Press "#" button to ready for next entry

(b) Verification

Problem: Interrogate programming to assure proper function of programming example, above.

Execution:
- -Press "#" button to ready for sequence
- -Enter "1" for Monday
- -Enter "18" for 6:00 pm
- -Enter "2" for 2nd half hr.
- -Enter "1" for interrogation of switch function No. 1 and observe function light "ON" and lit
- -Enter "2" for interrogation of switch function No. 2 and observe function light "ON" and lit
- -Press "C" button to be ready for next entry or interrogation.

7. Additional Features

While the original concept was to provide for switching between two possible channels; other switching combinations are feasible.

The use of the microprocessor with a matrix switch is illustrated in Fig. 6. The control function for 2 matrix switches is shown under command of the programmer. The design was to provide for any one of eight input signals to be switched to 4 outputs.

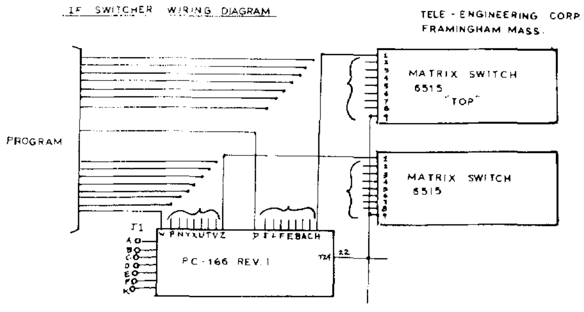


Fig. 6

When the switching action takes place remotely from the control area, a remote unit is used. A typical installation is indicated in Fig. 7. A conventional telephone line is used for a link and a touch tone phone is used to access the memory. The command condition of a given time slot is indicated by different audio tones. Using the programming procedure outlined in section 6 a time slot is addressed and the appropriate command inserted. Provisions can be made for a scope display indicating the status of each time slot. The data is presented as a dot matrix and can be displayed on a conventional TV set using a video channel where such is available.

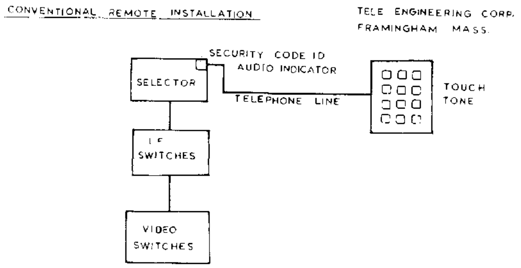


Fig. 7

As mentioned previously, a security unit can be provided which denies access to unauthorized personnel. The functioning of this unit is illustrated in Fig. 8. The security code is inserted with a microswitch using BCD code. When the unit is addressed through the telephone the first two digits are compared with the code in memory. If these numbers correspond to the preset code, the latch is activated thereby allowing access to the keyboard entry.

The following binary settings are used for the security code:

	SECOND DIGIT				FIRST DIGIT			
SWITCH	8	7	6	5	4	3	2	1
0	1	0	1	0	1	0	1	0
1	0	0	0	1	0	0	0	1
2	0	0	1	0	0	0	1	0
3	0	0	1	1	0	0	1	1
4	0	1	0	0	0	1	0	0
5	0	1	0	1	0	1	0	1
6	0	1	1	0	0	1	1	0
7	0	1	1	1	0	1	1	1
8	1	0	0	0	1	0	0	0
9	1	0	0	1	1	0	0	1

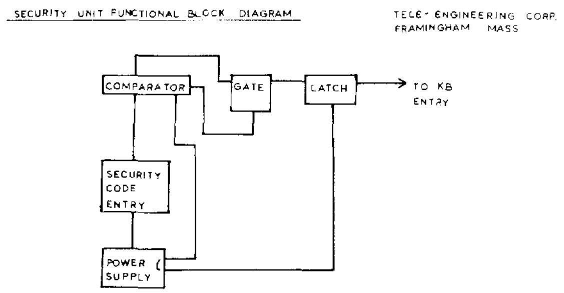
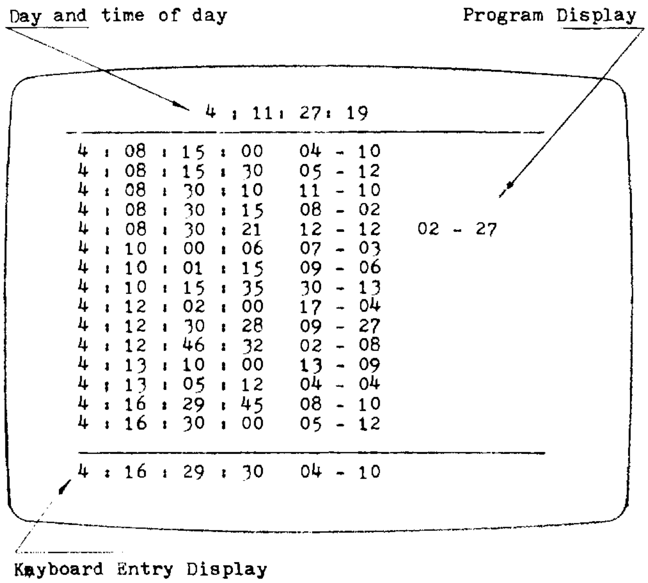


Fig. 8

In order to protect from memory loss resulting from power failures, a standby power supply is provided. This will allow the unit to continue operation for up to 48 hours without primary power. In order to save energy, no display is shown during power outages. When power is restored, the clock display will indicate an error signal, however no error will exist in the clock. The display error indication is removed when the set switch is activated.

8. Use of Advanced Microprocessors

The applications discussed in the previous section have been accomplished with a microprocessor designed for the specific parameters outlined. Other applications required more sophistication of design and more complexity. One such system has the capability of 2000 program changes per week. The time slots can be adjusted in length to the second. The matrix 2000 can control a matrix switching system of up to 400 switching functions. The programming is displayed on a cathode ray as shown in Fig. 9. A section of the program of up to 15 lines can be displayed at any one time. One line is reserved for most recent keyboard entry. A printer is provided which records each executed command. It can also record program that is in storage.



CATHODE RAY TUBE DISPLAY

Fig. 9

Another processor development is the control of switching at a number of locations remotely from one central facility. This involves the basic 2000 unit with encoders that convert switch commands to a VF signal that can be transmitted on telephone line or a channel of the system. The confirmation of the command is encoded and transmitted on a return path. The layout of such an application is indicated in Fig. 10.

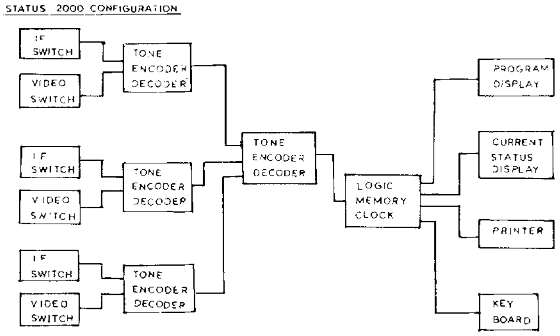


Fig. 10

This miniprocessor was also employed in a status monitoring application. This involves polling of status elements and selectively allowing access of an individual branch indicating the status. The resulting indication of current status is displayed on a CRT as shown in Fig. 11.

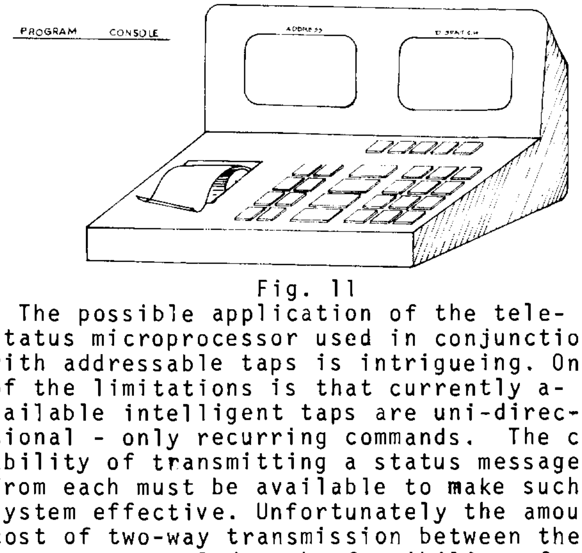


Fig. 11

The possible application of the telestatus microprocessor used in conjunction with addressable taps is intrigueing. One of the limitations is that currently available intelligent taps are uni-directional - only recurring commands. The capability of transmitting a status message from each must be available to make such a system effective. Unfortunately the amount cost of two-way transmission between the processor precludes the feasibility of this application at this time. One of the available possibilities is the use of this system in an application where there are more than 20 subscribers at one location such as apartment complexes. Such a cluster can be cost effective for telestatus control of taps.

CONCLUSION

In this paper we have indicated how microprocessors can be effectively used to enhance the operation of a CATV system. With further development and more refinement of IF and video switches, there can be an even greater realization of advantages.

TECHNICAL ASPECTS OF TWO-WAY CATV SYSTEMS IN GERMANY

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ABSTRACT

In the near future pilot projects for two-way cable television are to be introduced in the Federal Republic of Germany. In preparation for these, investigations are being carried out, using a laboratory system, of a variety of services and of the technology necessary to accommodate large numbers of subscribers. The system described in this paper was conceived on the basis of these investigations.

1.0 Introduction

In the Federal Republic of Germany there are cable television networks in existence in Nuremberg, Hamburg and Düsseldorf, which belong to the Federal Ministry of Posts and Telecommunications. None of these is a two-way system. They were set up primarily to serve areas lying in the shadow of high eminences, where normal reception would be poor. There are legal stipulations that preclude the operation of two-way systems.

However, the Commission for the Development of the Telecommunication System (KtK), set up by the German Federal Government in 1974, recommended in its concluding report that a number of CATV pilot projects be introduced, in order to test telecommunications services and alternative ways of organizing their administration.

A decision is due to be taken during the next few months on whether several large-scale pilot two-way television networks are to be set up in the Federal Republic of Germany. These would then offer a variety of interactive services to a large number of subscribers.

In preparation for these pilot field projects a two-way cable television laboratory project is being set up at the Heinrich-Hertz-Institute, financed by the Federal Ministry of Science and Technology.

This latter project is based on the recognition that prior laboratory work is necessary to

- evolve new telecommunications services and develop known ones further, and
- examine the technical and theoretical problems of the necessary technical system.

The interactive CATV systems known today mainly offer only very limited interactive services to a restricted group of subscribers. Very often a return channel foreign to the system is employed, with all the resulting disadvantages. The limitations with regard to the bandwidth demand, the complexity of the services, the number of simultaneously active subscribers, the privacy of the message, etc. were removed to a significant extent in the laboratory system design, enabling a large number of complex telecommunications services to be offered to a large number of subscribers.

The CATV system thus specified undoubtedly exceeds the scope of the pilot field projects to be undertaken in the near future, in respect of the telecommunications services, the frequency of use and the complexity assumed here. However, precisely as a result of this apparent exaggeration, fundamental problems are recognized and solved.

2.0 The Demands on the Technical System

To determine the traffic volume certain assumptions were made:

- the planned CATV system would serve 10,000 subscribers, who could all use the system interactively;
- a maximum of 1,000 subscribers would be interactive simultaneously.

Type of Service	Expected Number of Simultaneous Users	Examples, Remarks
TV/Teletext	Number not Restricted	Programmes for Unlimited Distribution
Pay TV	Number not Technically Restricted	Programmes for Limited Distribution
Simple Services	100	Mailbox, Billing etc.
Games and Information Services	700	Inter-Subscriber Games, Subscriber-Computer Games Information about Transport, Culture, Medicine etc. in some case with additional Audio and Video Information
Complex Services	200	Computer Access, CAI, supplied with Audio und Video Information Services with Flexible Structure of Man-Machine Dialogue

Fig. 1 Different Types of Telecommunications Services

The evaluation of the assumed traffic volume with the given spectrum of services produced the following further parameters:

. in the downstream direction, in addition to the television distribution programmes, approx. 200 to 300 individual television channels,

. up to 1,000 smallband digital channels with bit rates of 9.6 kbit/s,

. approx. 90 speech channels in downstream and upstream directions, and

. approx. 20 television channels in the upstream direction are required;

. the central facility must be capable of dealing with a maximum of 60 interactions per second;

. up to 15,000 still pictures must be available for random access.

In addition to the traffic volume, a further important parameter is the service quality. Essential factors here are

. the reaction time of the system during a dialogue, which must not exceed 3 seconds,

. a high degree of message privacy with interactive services,

. the user language,

. the construction of the home terminal, with regard both to anthropotechnical design and high-quality presentation of information.

3.0 The Technical System

Fig. 2 shows the structure of the interactive CATV system, divided into subsystems.

3.1 The Computer System

The tasks of the computer system can be divided into two areas:

a) the offering and carrying out of the services (service-specific tasks),

b) the monitoring and control of the system (system-specific tasks).

The particular problem of this computer system consists in coping with the high number of simultaneously interactive subscribers (1,000). In the worst case approx. 60 interactions must be dealt with per second. In all, the subscribers have access to approx. 300 services with a total programme size of approx. 25 MB.

From these figures it follows that with a solution involving minicomputers that have per processor a maximum memory capacity of apprx. 2 MB it is never possible to keep all the programmes resident in the memory at once, and therefore very efficient task management is especially necessary.

The hardware concept (fig. 3) provides for a multi-processor system, in which the individual processors are connected via a bus. In addition, the most important processors are connected via a shared memory. Several processors can be connected to the bus, so that an extension of the hardware is no problem.

The terminal processor receives all the interactions coming from the subscribers via the digital transmission system and processes the subscriber-specific information. The service computer deals with the content of the interaction and conveys the information direct to the subscriber via the digital transmission system. If, during a dialogue, information in the form of still pictures, moving-picture sequences or audio is necessary, the task of providing it is passed to the controller. This latter computer controls and administers the storage-system equipment.

3.2 The Transmission Network

On account of the high number of individual broadband channels required for dealing with the individual services, the total area served is divided into approx. 10 sub-areas. Each sub-area is supplied with the individual programmes via its own cable, which transmits 30 broadband channels arranged as adjacent channels. For the individual programmes the connection of the sub-areas to the central facility is star-shape, while on a second cable the approx. 12 general distribution programmes are transmitted via a tree network to the whole area served. For a transition period, in which it will not yet be possible to assume that subscribers have television sets capable of receiving adjacent channels, the unlimited distribution programmes will not be transmitted in adjacent channels.

The network is divided into the active levels A and B, and the passive levels C, D and E (fig. 4). On the A level, the programmes for several sub-areas are normally transmitted. One cable carries the unlimited distribution programmes; one cable - a separate one for each sub-area - transmits the individual programmes; a further cable transmits for each of several sub-areas the 5 broadband upstream channels which are lined up in blocks, each with one interjacent channel that is not used. The 5 broadband upstream channels provided for each sub-area consist of 4 video channels and a broadband channel carrying the signals of the digital transmission system for the transmission of data and speech.

In its basic structure the two-way network is a tree network, since the distribution of programmes continues to be an important task. However, a pure tree network has a very unfavourable effect on the transmission of individual interactive programmes, since it provides no guarantee either of privacy when information is directed to a particular subscriber or of freedom from interference when information is transmitted to the central facility.

In order to avoid these disadvantages, groups of subscribers are connected in star-shape via the E level to a so-called forefield installation (German "Vorfeldeinrichtung VFE"), which is linked to the D level. In the forefield installation video- and data-switching is carried out, controlled by the central facility, so that each subscriber only receives the information intended for him. For the video signals this switching is performed as follows: the signals in the channel assigned to a particular subscriber are transferred, by means of a converter controlled from the central facility, from the 30-channel cable to a channel in the 12-channel cable not occupied in the distribution direction, and are transmitted to the subscriber on this channel (fig. 5). In the upstream direction the forefield installation guarantees that the data or speech signals are assigned in sequence to the digital transmission channels and that broadband channels are assigned for video transmission to the central facility. Through these functions overlapping of signals is avoided and interference from the subscriber area, e.g. as a result of defects in subscribers' sets, is kept out of the upstream network.

3.3 The Digital Transmission System

The digital transmission system organizes the transmission of digital information between the central facility and the subscriber terminals. There are three types of connection:

1) data dialogue connections

Data must be transmitted from the computer to a subscriber at a relatively high bit rate. Subsequent to this there is a pause of up to 60 s, as the subscriber processes the information. The subsequent subscriber's reply is relatively short and should in turn be transmitted at a high bit rate. The digital transmission system only allocates these connections involving a channel of high bit rate when they are needed.

2) remote control connections

The transmission of control commands and measured data requires a connection of short duration, in which only a few bits are transmitted.

3) speech connections

For the transmission of speech (in DPCM) about 90 channels with a bandwidth of 8 kHz are required. Channels with a transmission capacity of 64 kbit/s are available.

3.3.1 Organization of the Time Division Multiplex Transmission

The initiative for transmission comes exclusively from the control unit in the central facility.

Time is divided into so-called time slides. Within such a time slide the central facility transmits a downstream block consisting of an address section and a data section.

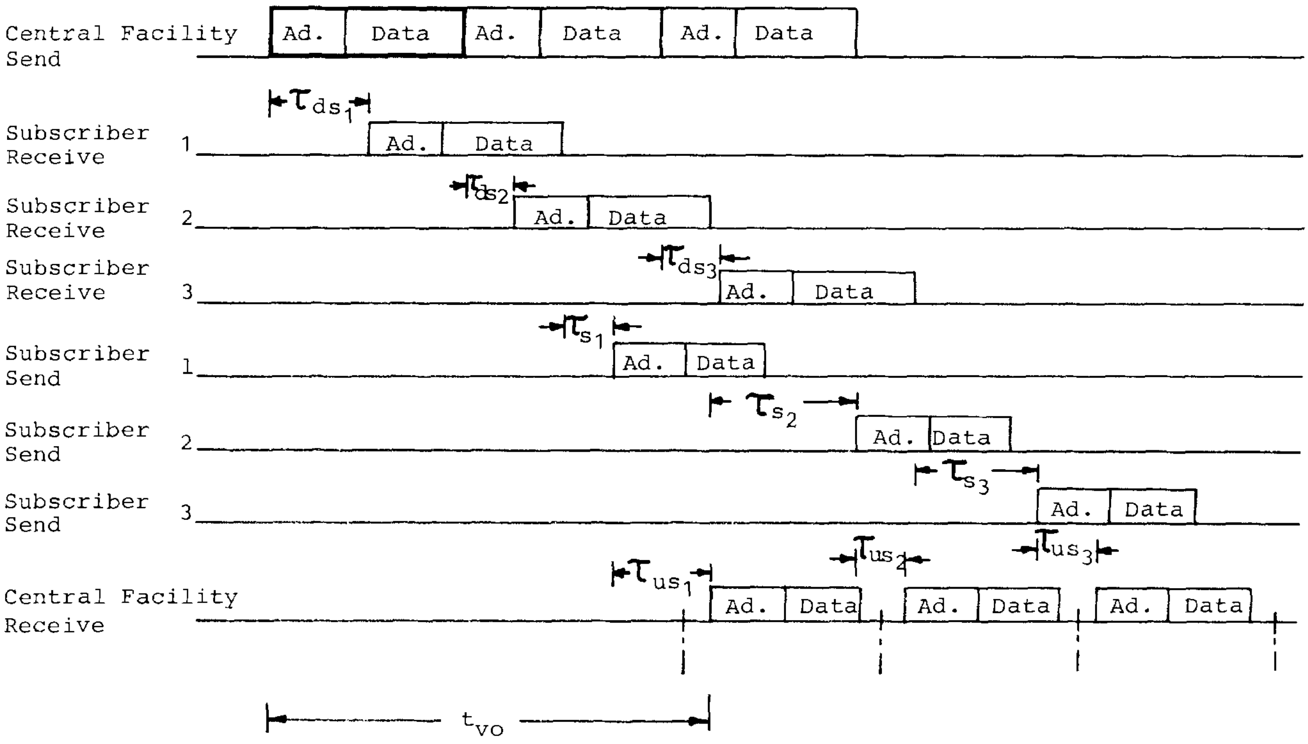

Fig. 6 Transmission Procedure

The address section contains the address of the subscriber for whom the information in the data section is intended. The subscriber recognizes his address and selects the information which follows it from the bit stream in the downstream network. The reception of a block is interpreted by the subscriber not only as a "reception of information" but also as a request to transmit. He can therefore send a data block to the central facility directly after receiving a block, during a time span corresponding to a time slide.

If this single procedure in each time slide is carried out with alternating subscribers and periodically repeated after n time slides for the individual subscriber, several subscribers are allocated to a channel in time multiplex. The time slides must be allocated in a specific order to the individual simultaneous connections.

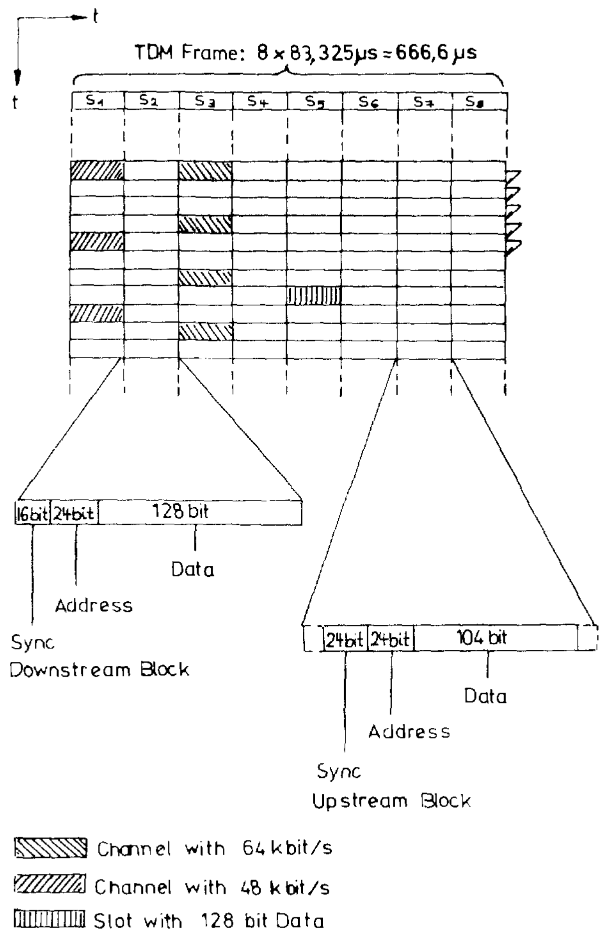

Fig. 7 Frame of the TDM System

In the upstream direction the system displays the same frame organization. The blocks have the same bit rate as those of the downstream network, but are about 16 bit shorter, so as to equalize the delay times varying from subscriber to subscriber in the cable network. (In the subscriber unit, in addition, the possibility exists of equalizing the delay times in steps of 8 bits.)

3.3.2 Setting Up a Connection

In order to recognize the connection requirements of the subscriber, the digital transmission system sends out free calls at regular intervals, which request the subscriber desiring a connection to send a block containing his address and his connection requirement. The number of free calls is much larger than the number of connection requirements. If overloading occurs despite this, none of the subscribers receives a reply. They repeat the connection requirement after a random number of free calls.

3.4 The Head End

The head end constists of cable-transmission and cable-receiving units. In a cable-transmission unit the 12 distribution programmes, consisting of off-air programmes and pay TV, are brought together in non-adjacent channels and transmitted via the network described above.

In seperate cable-transmission units for each sub-area, 30 channels are available for the transmission of the individual programmes and the digital transmission system. To assimilate the range of the 30-channel system to the 12-channel system, the individual video signals are transmitted in a synchronous mode, and the picture carriers are related in certain phases.

In the cable-receiving units the signals transmitted to the central facility from the sub-areas in groups of 5 channels for each sub-area are received and demodulated.

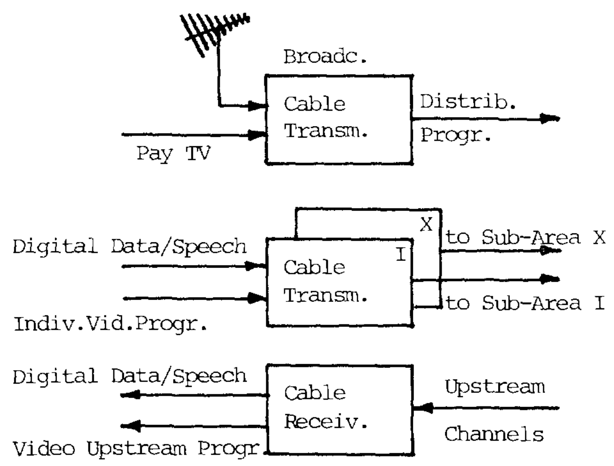

Fig. 8 Head End

3.5 The Storage System for Audiovisual Information

The storage system makes the audiovisual information, consisting of still pictures, moving-picture sequences and audio, available for the services.

During peak hours simultaneous access to approx. 200 different still pictures, approx. 50 moving-picture sequences and approx. 90 audio sequences is to be expected. At such times all the services offered will be used, on average, by at least one subscriber. Since it is intended that during a service access to the video or audio information should take less than 3 secs., all the audiovisual information must be available to many subscribers for random access.

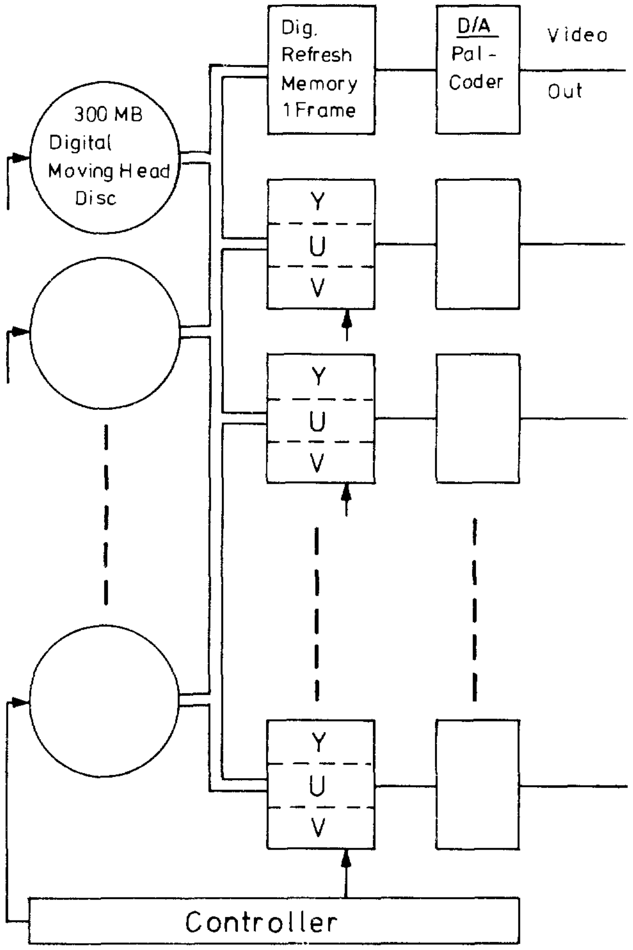

Fig. 9 Storage Unit for Still-Pictures

The still pictures are recorded, with separate luminance and chrominance signals, in digital form on moving head discs. When a still picture is to be transmitted to a subscriber, the video information is selected from the moving head disc concerned, under the influence of a controller, and buffered in a digital refresh memory, which is then selected cyclically. This signal is converted back into analogue form, PAL-coded and transmitted to the cable-transmission unit. If subscribers have refresh memories, only an addressed single frame is transmitted to them, which leads to a lower number of refresh memories, PAL-coders and modulators in the central facility, and to a reduction in the transmission capacity required in the network.

Audio or speech signals are recorded with a band width of 8 kHz in digital form (DPCM) on moving head discs. The storage organization resembles to a considerable degree that of the still pictures. The speech signals are read at a bit rate of 64 kbit/s from the buffers and are transmitted to the subscribers in time-division multiplex together with data via the digital transmission system.

For moving pictures there is as yet no practicable equipment for random and multi-user access for a programme quantity of approx. 200 hours. The moving-picture storage is organized in such a way that when a service involving moving pictures is requested, the desired video information is made available in the form of video cassettes, by means of manual or automatic loading of cassette-players. The video sequence is controlled by the services programme.

3.6 The Home Terminal

The home terminal can be extended in steps. The simplest version for interactive services consists of a TV set, a refresh memory for alpha-numerical information and a simple numeric keyboard with a few special keys. With this, selection can be made from among a great many interactive programmes, especially those constructed according to the so-called menu technique.

In its most complex form the home terminal comprises an alpha-numeric keyboard, a refresh memory for alpha-numerical information, graphic and video still pictures, a printer and a microprocessor, which enables a part of the programme or programme sections to be processed directly by the subscriber's equipment. As a result of this decentralization a reduction of the load on the central facility and, above all, a shortening of the reaction times is envisaged.

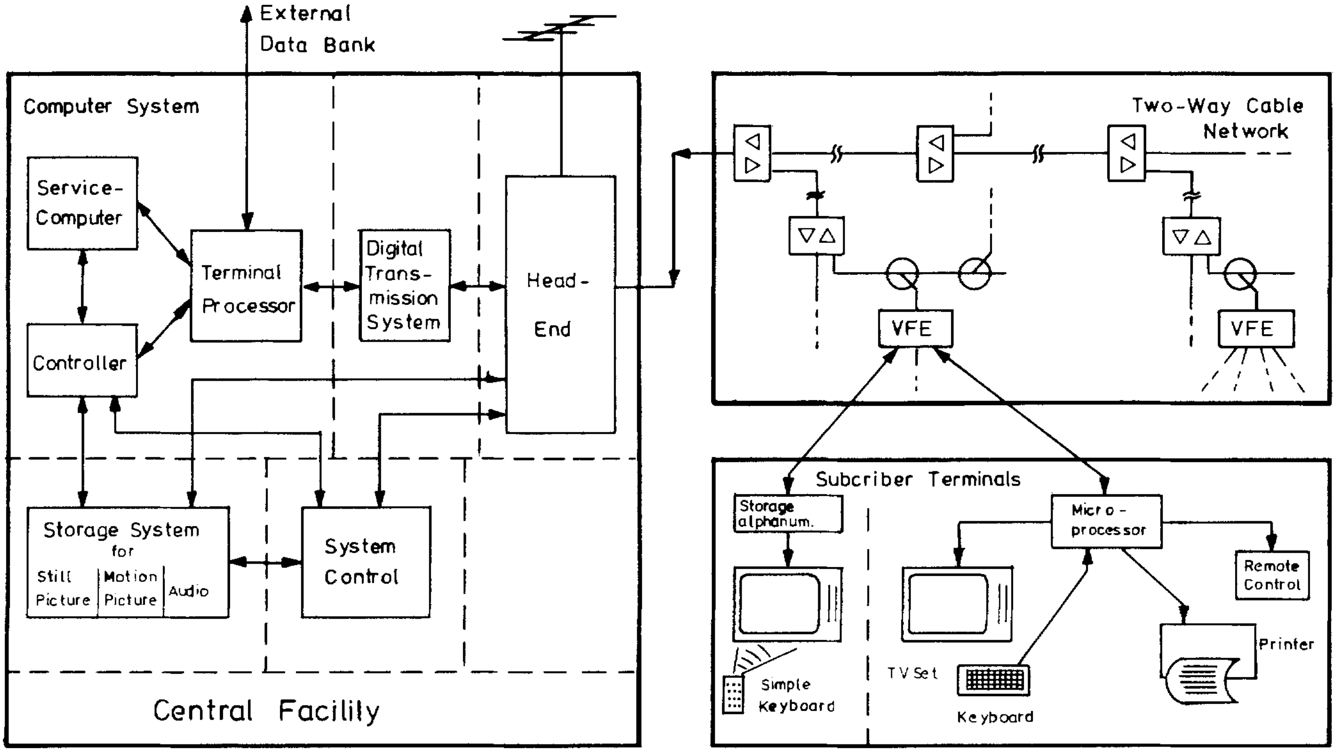

Fig. 2 Interactive CATV System

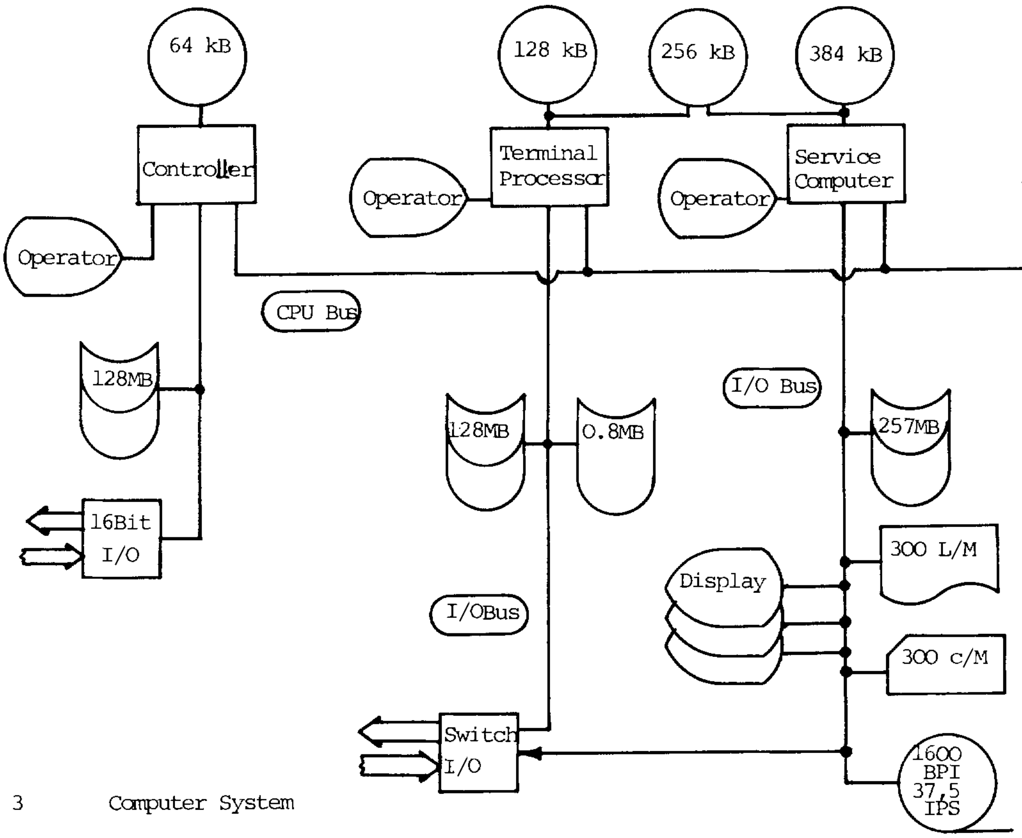

Fig. 3 Computer System

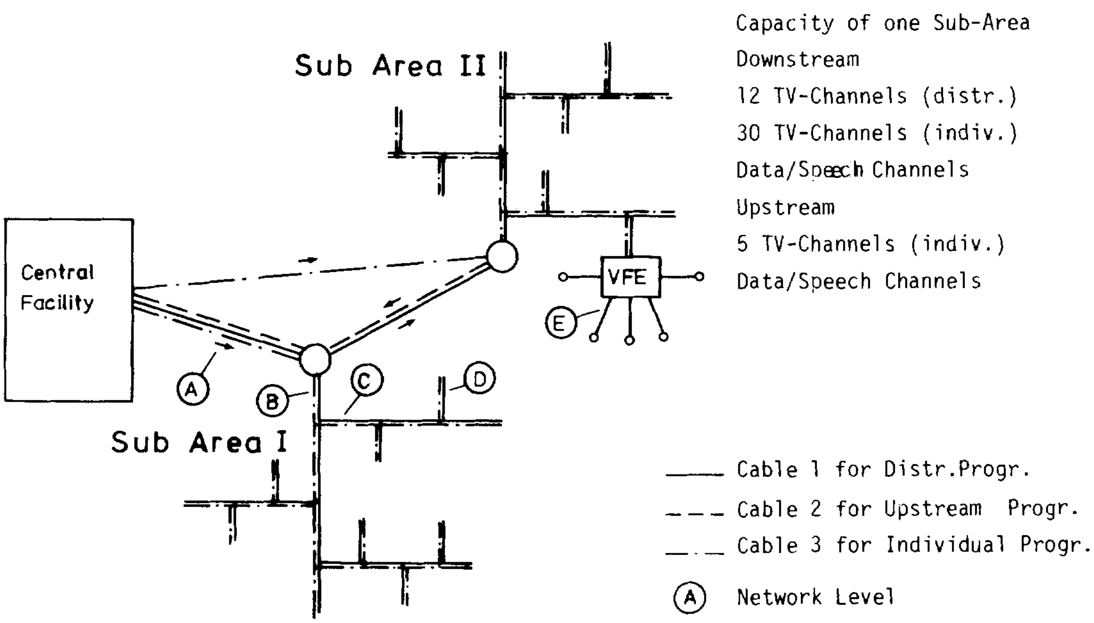

Fig. 4 Schematic Representation of the Cable Network

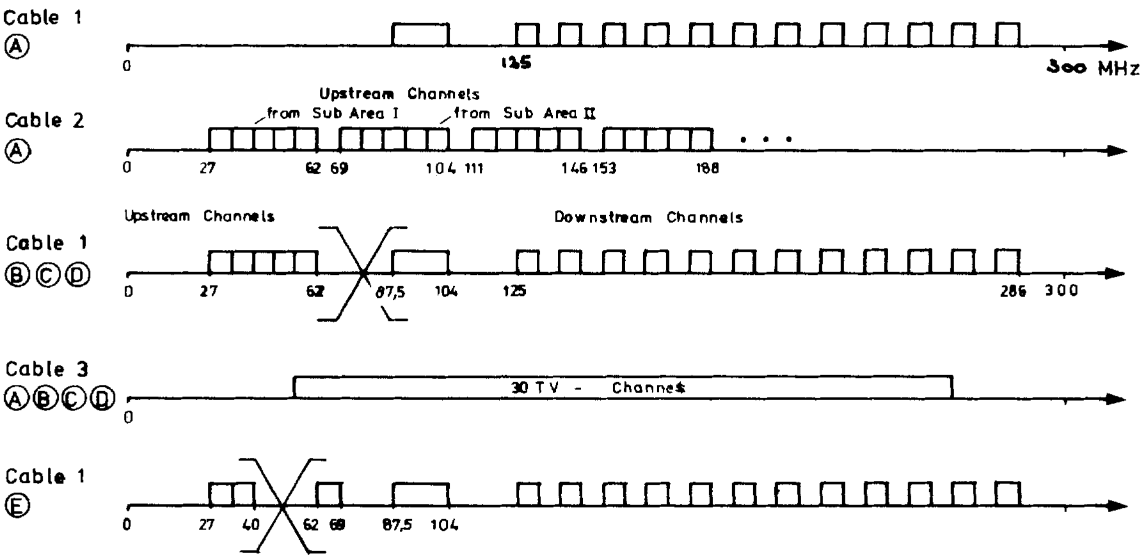

Fig. 5 Frequency Allocation

TECHNICAL CONSIDERATIONS IN THE DESIGN AND OPERATION OF A TWO-WAY CATV SYSTEM IN A MAJOR MARKET AREA

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ABSTRACT

The design and operation of a two-way CATV system in a major metropolitan market area involves a number of unique problems. Following a review of development in past years, the current design parameters are discussed and the author's recommendations are presented for the specification, design and operation of a contemporary two-way broadband communications system.

SIGNAL TRANSMISSION REQUIREMENTS:

The nature of the two-way CATV system is essentially defined by the characteristics of the signal transmission requirements. In contemporary systems serving major metropolitan centers the following signal transmission requirements are considered essential:

1. Thirty (30), or more, downstream television channels available to all subscribers with very high quality video reception,

2. Twenty (20) F. M. radio channels in the normal F. M. radio frequency band (88-108 MHz), with spacing for stereo modulation,

3. Twelve (12) to Twenty (20) additional television channels available to limited areas for distribution of limited access nonentertainment television programs (municipal, medical, educational, industrial, etc.),

4. 5 to 30 MHz reverse (upstream) non-television transmission facilities from all residential subscribers to a central data collection center,

5. Five (5), minimum, reverse (upstream) television channels of high quality. F. M. video modulated channels may be required in order to attain sufficient fidelity as to permit re-transmission without noticeable video degradation.

The downstream distribution requirements are generally known to CATV system engineers and present no new or difficult problems. However, the upstream transmission system represents a new technology that has not been fully demonstrated on an extensive system. In addition, there are certain avoidable problems associated with the possible interference between the upstream and downstream transmissions which should be considered in the system design.

ORIGINAL DESIGNS AND DEVELOPMENT:

There are several basic designs for two-way systems which have been field tested and the advantages and limitations reported in the trade press and technical seminars. Early systems used a separate coaxial cable from each origination location to the "headend". To minimize noise build-up a low frequency (below Channel 2) video carrier was used so that amplifiers could be spaced farther apart in the "return line". This "sub-VHF" band (5.75 to 47.75 MHz) was generally converted to the VHF high band (174 to 216 MHz) for reception and the channels were assigned appropriate numerical designation (T-7, T-8,.....T-13).

A natural development occurred in the early 70's wherein the "sub-VHF" band was diplexed onto the CATV system in the reverse (upstream) direction. The complimentary filters which provided the isolation between the upstream "sub-VHF" and the downstream "VHF" transmissions were the subject of intensive research and development. The early "sub-split" systems were designed to provide downstream transmission from 54 to approximately 250 MHz and upstream transmission from 5 to 30 MHz. These early two-way (on a single coaxial cable) systems exhibited several severe limitations, although most "blue sky" system operators chose to ignore them.

It is, however, generally recognized today that such sub-low band frequency division two-way multiplexed systems are not suitable for major market system use because:

1. Phase delay, due to the cascade of large

numbers of the complimentary filters, causes intolerable video distortion in the higher frequency "sub-VHF" channels and in the lower frequency VHF channels.

2. Noise and ingress interference is excessive due to the branching nature of the system.

3. Upstream transmission bandwidth, of 5 to 30 MHz does not provide space for sufficient video channels.

SFDT SYSTEM: (See Fig. Nos. 1 & 2)

As a consequence, a system was developed to provide the two-way facilities without these limitations. This system is generally referred to as the "Single-Feeder, Dual Trunk" (SFDT) design.

The essential components of the SFDT system are:

(a) Two independent trunk cables ("A" and "B") with complete physical separation to achieve maximum isolation. Trunk "A" provides conventional CATV multi-channel downstream only distribution (50 - 300 MHz). Trunk "B" operates as a "mid-split" two-way transmission system with downstream distribution (174 - 300 MHz) and upstream transmission (5 - 110 MHz).

(b) Two-way distribution, or feeder, with downstream supplied from the "A" trunk (50-300 MHz) and the upstream signals of 5 to 30 MHz diplexed through the line extender amplifiers from each subscriber drop to the bridging or distribution amplifier.

(c) The sub VHF (5-30 MHz) upstream signals are separated from the downstream signals by highpass/lowpass filters at the bridging or distribution amplifier and are coupled through a "seventh port" to the "B" cable reverse amplifier. This "seventh port" amplifier is unique inasmuch as the conventional downstream only amplifier housing has only six (6) ports: input and output trunk ports plus four (4) distribution ports.

(d) The seventh port in the "B" cable amplifier provides a means to couple the 5 to 30 MHz signals to the 5 to 110 MHz upstream system such that:

(i) An automatic switch opens to block the insertion of noise and interference when actual sub-low signals are not being transmitted,

(ii) Amplifier response, and low-pass filters, prevent noise and interference from the subscriber drops and "A" cable distribution system from appearing on the "B" cable -- particularly in the 45 to 110 MHz bandwidth. This frequency band is reserved for "preferred" reverse video transmission.

It can, therefore, easily be seen that the SFDT system provides all of the signal transmission requirements which are considered essential for service in contemporary systems serving major metropolitan areas. Such systems have been extensively field tested and are available from all major equipment manufacturers. There are, nevertheless, certain precautions that should be taken to avoid crosstalk and interference/noise problems.

THE REVERSE SYSTEM "NOISE TREE":

Although "thermal" noise contributed by the reverse amplifiers in the upstream transmission system can be a significant problem, and can severely limit the quality of video channels which are carried, the interference from r.f. ingress leakage is of greater concern. C.B. radio and foreign radio stations can be very "active" in the sub-VHF frequency band and can easily enter the upstream system through the unshielded 300-Ohm twin lead on the customer's side of the matching transformer or through inadequately shielded drop cables. The preferred reverse video band (45 - 110 MHz) is subject to interference from lowband television and FM radio transmission and other radio frequency interference and must be well isolated.

If the subscriber drop is, therefore, assumed to be a potential source of noise and interference which will be amplified and combined in the upstream transmission, it is apparant that a filter which excludes all unnecessary interference should be used in the 5 to 30 MHz upstream circuit. Further, a squelched or switched upstream amplifier would provide additional isolation from such interference. The relative merits of a squelched reverse amplifier vs. a code-operated switch may be debated, and may vary with the state-of-the-art, but one or the other would seem to be imperative in a contemporary system for two-way service.

It has been demonstrated [1] that data error rates on reverse transmissions within two-

(1) Reliability Engineering Report No. 75-06, February 9, 1975, Jerrold Electronics Corporation by S. Allen (Unpublished)

way frequency division multiplexed systems extending only twelve (12) amplifiers away from the headend exceed tolerable rates. The use of time sharing techniques to control the effect of noise-contributed errors has been shown to be adequate for such sensitive applications as home security system communication requirements.[2]

COMPONENT SELECTION:

One of the lessons which was learned through early two-way system design, construction and operation was the requirement to fully consider the sub-low frequency band in the selection of system components. Passive devices must be carefully selected to assure the desired reverse attenuation vs. frequency characteristics. Drop cable, connectors and equipment housings must exhibit high resistance to signal leakage, particularly in the sub-low band frequencies. Cable and electronic equipment which was designed and tested for use at 50 MHz and higher frequencies should NOT be assumed to be adequate for sub-VHF frequency use. Likewise, dual cable forward only transmission system equipment and design techniques should not be assumed to be adequate for forward-reverse system operation with common frequency use such as the SFDT system. The isolation required in the two-way system is considerably greater than that required in a dual cable downstream only distribution system. This may be attributed to the branched design of CATV systems; and to the consequent addition of all noise and interference at the central hub or headend vs. the single upstream signal.

SYSTEM DESIGN AND CONSTRUCTION:

It is therefore obvious that system test points should not be constructed so as to violate this high isolation requirement -- with lengths of parallel drop cable down the pole. Significant r. f. currents will exist on the outer surface of solid aluminum sheath coaxial cable with a wall thickness of less than 8 mils and a high level 5 MHz signal impressed thereon. Conventional 40% to 50% braid coverage drop cable provides too little shielding at any frequency.

The a.c. powering is also critical as a potential problem in isolation. Separate ferroresonant regulating transformers and diplex couplers are recommended. In some cases it has been necessary to cascade the a.c. power couplers in order to obtain the high isolation required.

Separate trunk amplifier housings, preferably mounted "back-to-back", are recommended. These housings should demonstrate effective r.f. shielding at all frequencies within the 5 to 300 MHz bandwidth.

(2) "The Quiet Way to Link Upstream" by Cecil C. Ho , TOCOM, Inc. (Unpublished)

Although the conventional amplitude modulation used for television video transmission may at first appear to be a "worst-case" situation, it should be remembered that the upstream data signals may be pulse code modulated and contain relatively high level harmonic components. Cross talk from such signals can have a devastating effect upon the video signals.[3]

As a final precaution to be observed in the design of a CATV system within a major market area the system maps should be on a scale of 100 ft./inch instead of the conventional 200 ft./inch scale. The increased system complexity, together with the usually higher dwelling density in major market areas, will require more spacious system layout for legibility.

CONCLUSION:

In summary, it is suggested that great care be given the design and construction of systems within the major metropolitan areas. Although initially intended only for downstream signal distribution with, perhaps, some widely scattered upstream transmission of locally originated television signals, there are strong indications that complete two-way service will be required before complete depreciation write-off. Some minor design and construction modification, together with careful selection of cable and equipment, can avoid the major expense and confusion of extensive design change and equipment replacement when two-way operation is desired.

REFERENCE LIST

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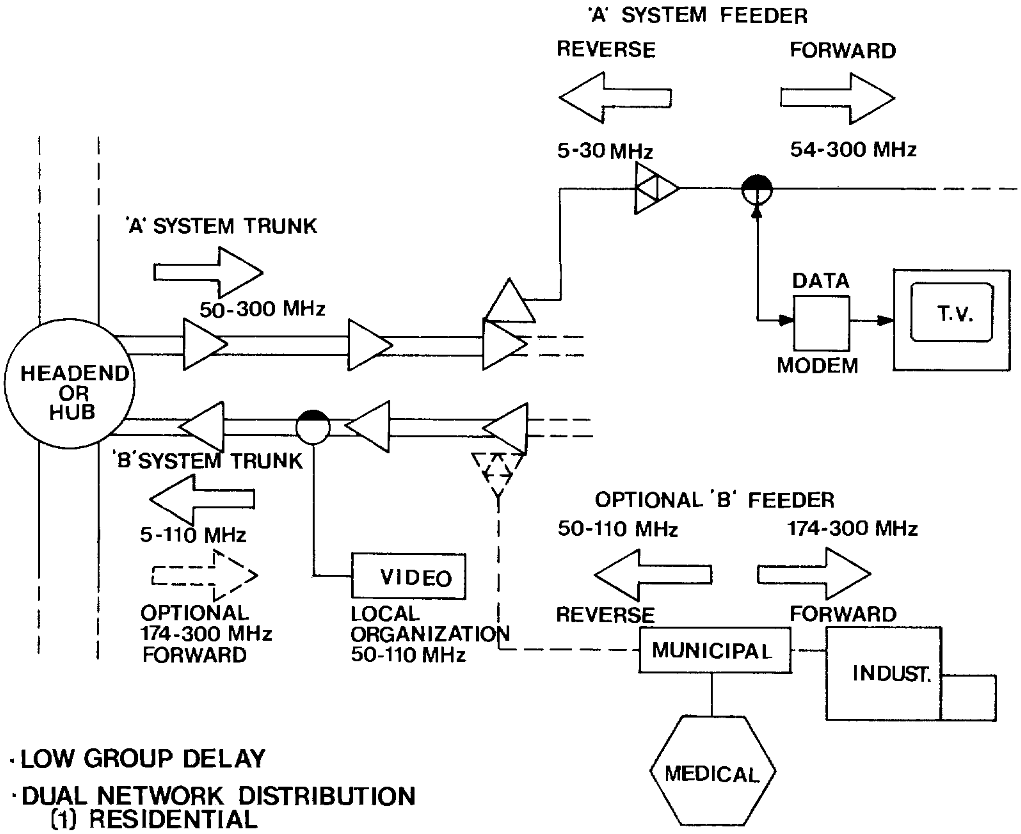
4. "A Study of Aluminum Cable-Connector Interfaces and Their Effect on CATV System RF Ingress" by Eric Winston, NCTA Technical Transcript of 22nd Annual Convention, June 17-20, 1973.

5. "Considerations for Reverse Signals in the Feeder Lines" by Robert Wilson, NCTA Technical Transcript of 22nd Annual Convention, June 17-20, 1973.

(3) "Mutual Interference Effects in Data/CATV Systems" by Charles E. Sampson, NCTA Convention 1973.

DUAL TRUNK CABLE
SINGLE DISTRIBUTION CABLE



- LOW GROUP DELAY
- DUAL NETWORK DISTRIBUTION
  (1) RESIDENTIAL
  (2) LIMITED ACCESS
- LOW NOISE VIDEO RETURN (50-110 MHz) WITH DATA RETURN (5-30 MHz)
- OPTIONAL ADDITIONAL LIMITED ACCESS FORWARD DISTRIBUTION

FIGURE 1

SYSTEM STATION DIAGRAMS

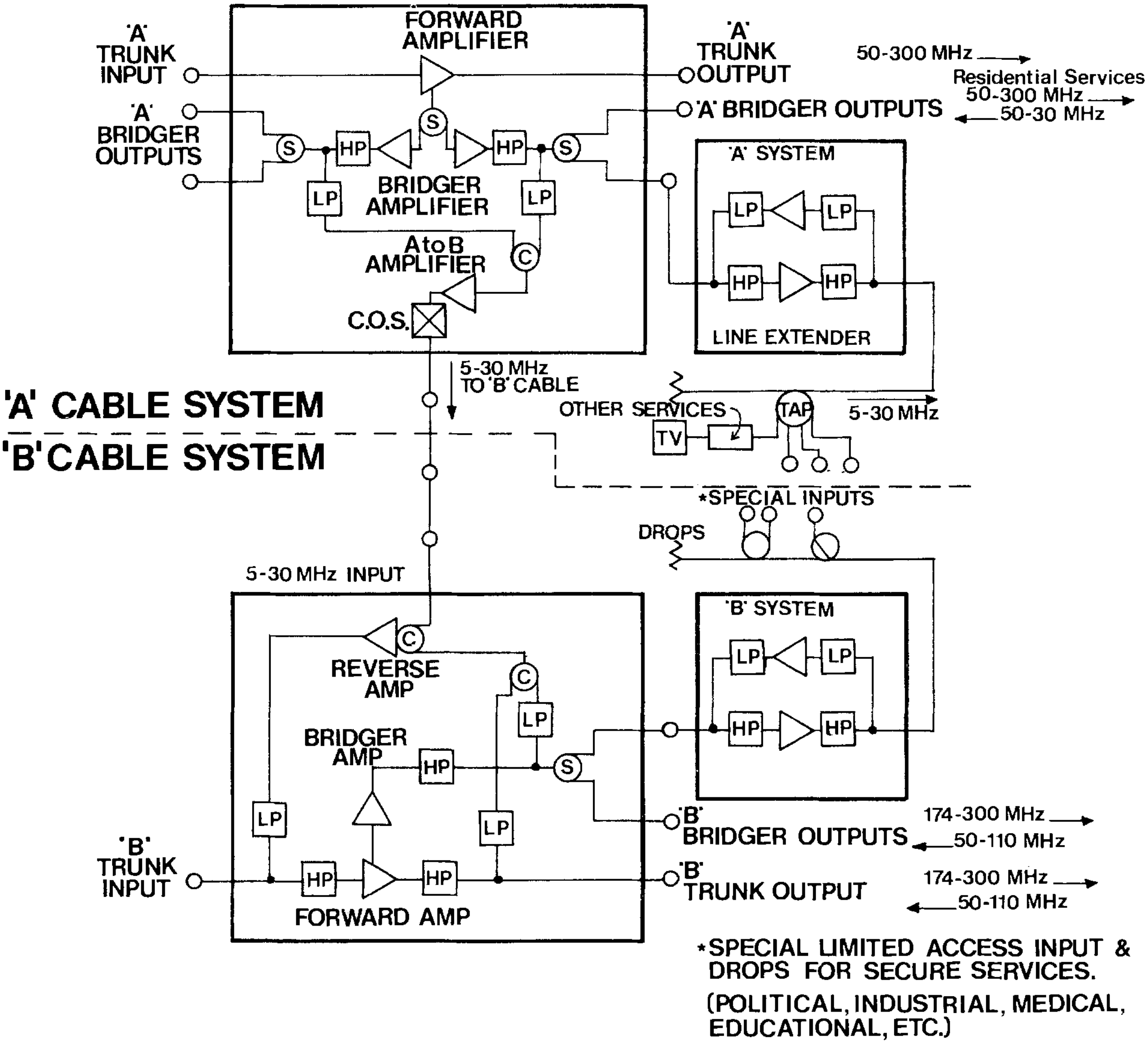


FIGURE 2

TECHNICAL PERSONNEL-BUY THEM, STEAL THEM OR RAISE YOUR OWN

Glenn Chambers

American Television and Communications Corporation
Englewood, Colorado

ABSTRACT:
A look at the need for trained technical personnel and some methods used to get them. This paper covers advertising, recruiting, interviews and the problems with testing. It covers union employee testing and training, along with some sample questions. Employee incentives are discussed, along with technical schools and home study courses.

One of the biggest problems facing the CATV industry today is a shortage of trained technical personnel. It is a situation that is steadily growing worse and, unless steps are taken, will eventually face you all.

To help alleviate the problem, at least temporarily, most companies have resorted to three basic methods of filling their technical personnel needs. Those three ways are:

a. To buy them. Simply offering more money, benefits and/or titles than the person is presently getting. This will work well until another company offers them even more.
b. To steal them. Contracting people who work for other companies and offering them jobs. This is usually combined with buying, in that you offer them bigger titles or salaries. This method has the same inherent problems as buying people.
c. Raising your own. This is by far the most used and most successful method. It simply means hiring someone that you feel has the other necessary qualifications but lacks technical training. This can be an expensive method, depending on the amount and quality of training that you provide. I feel that it is money well spent, since you also get some other benefits not possible through either buying or stealing.

Even if your company subscribes to the "Raise Your Own" theory, there will be times when you simply cannot afford the time to train someone or you immediately need someone with special skills or experience. In these cases, you will probably want to do some advertising, usually in trade magazines or newspapers, or use some other method of recruiting.

In the companies in which I have been employed, we have tried a great many ways of filling our needs for experienced help. We have tried the trade journals, newspapers, specialized CATV schools, employment agencies, and even some buying and stealing. A lot of our efforts have been less than totally successful. We have learned quite a few things not to do, and even a few that work.

The poorest ads that we have ever run are the "blind ads". I'm sure all of you have seen these, and maybe have even run some of them. They usually consist of three or four lines, barely telling that a job is available somewhere, in some company, doing something, for some salary. On the handouts, I have a typical blind ad, shown in figure 1, that was taken from a trade journal. I changed the box number, just in case the person who inserted it is here. As you can see, this ad does not really tell you anything.

FIGURE ONE

> CHIEF TECHNICIAN
> Needed immediately, five years experience and first class license required. Salary commensurate with ability. Reply in confidence to Box C-123.

Blind ads can even severely limit your responses, especially from the more intelligent technicians. Smart people who are looking to change jobs just don't answer blind ads. There is too much danger that the ad was placed by their own company and responding to it could be quite embarassing. There is only one real benefit that can come from a blind ad. You can find out if any of your own people are stupid enough to answer it and get rid of them.

Along these same lines, companies who don't include their names in their ads are also missing out. If you are not proud enough of your company to use it's name, how can you expect a stranger to want to work for you? With today's shortage of trained people, it doesn't bother me at all to admit that we could use more good people.

The most productive ads that I have run have contained a great deal of information about the job and the job benefits. In figure 2, you will see a recent ATC ad. In my opinion, this is a good ad, not just because my boss ran it, but because there is a lot of information there. I can't give you the exact numbers of responses to it, but I can tell you that they were quite gratifying.

Chief Engineers

American Television and Communications Corporation offers a growth opportunity for experienced cable TV engineers who want to become part of the company's aggressive management team.

ATC is seeking people to fill chief engineering positions in several of its major metropolitan area systems located in the East and Southeast.

Assume overall technical responsibility for modern cable facilities featuring

- 500+ miles of active plant
- operational pay-TV
- active two-way services

Solid technical experience and demonstrated administrative ability will make you qualified for top salary/benefit-package and future growth.

Send your resume and salary requirements to:

Larry Janes
Director, Field Engineering
American Television & Communications
20 Inverness Place East
Englewood, Colorado 80110

An Equal Opportunity Employer

FIGURE 2

The following is information that I feel even basic ads should contain, if they are expected to produce results.

1. Job title and job description.
2. Geographical location of the job.
3. Experience required.
4. Education and licensing required.
5. Salary range and special benefits.
6. Name of your company.
7. Name of the person to contact.
8. Your phone number and address.

The ad in figure 3 shows my recommended advertising format. This a ficticious ad, so don't try to respond to it.

CHIEF TECHNICIAN
Immediate opening in our Busytown, IL. system. New, 2 way, microwave, data, fiber-optics. Supervise entire technical staff. Min. 5 years exp. and 2nd class license. Salary over $14,000. Full benefits and education assistance. Call John Doe, (123)456-7890 or send resume and salary history to American Television and Communications Corp., 7300 N. Busy St. Busytown, IL., 09876
AN EQUAL OPPORTUNITY EMPLOYER

FIGURE 3

I think you will agree that you would respond to this ad more readily than to the ad in figure 1. This one costs a few dollars more, but I feel that it is money well spent.

When you get the responses to your ad, the really hard part starts. You have to interview the applicants, if they seem to meet your requirements, and select the one you feel is best suited to the job.

The actual interview questions will vary with each company and with each position to be filled. The best way for me to be sure to cover everything is to have a list of questions,prepared or revised especially for this job, and just follow it as much as possible.

If your company requires written testing of prospective employees, be very careful. One of the quickest ways to get your company into court these days is to let an applicant know that they have failed your written tests. There are hundreds of educators working today to come up with a legally fair method of grading tests. To be fair, a test must take into account the applicant's background, education, opportunities, ethnic heritage and even their parent's backgrounds. Unless you are a lot braver than I am, this is one can of worms you don't want to open.

The sample questions and answers shown in figure 4 will give you an idea of some testing problems. Believe it or not, these and similar answers must be considered correct and have actually appeared on our tests. Some of the answers may appear to be wrong or even stupid, but if you think so, don't ever let a good lawyer get you into court on them. He will eat you alive in front of a non-technical judge and jury.

If any of you have systems where the employees belong to a labor union, you are probably already aware of some testing problems. Most of the union contracts have very well defined job classifications and training requirements. In order for an employee to move into a higher job classification, some training and testing is usually required. When written tests are required, make sure that they exactly follow the job classification requirements and that you have documented proof that the employee has been given training in these areas. Before giving the tests to the employees, the tests and answers, copies of the descriptions, copies of training documentation, and copies of the union contract should all be reviewed by at least one educator and a good labor attorney for their written opinions. This is commonly known by the initials C.Y.A.

A problem that we have with union employee training is that you must pay him for any time spent studying. In order to document the training and studying, we set aside two (2) hours each week for this purpose and require attendance by the entire technical staff. The chief engineer or chief technician is then responsible for all lesson material presentation, lesson assistance and records keeping. The results to date have been very good. This same procedure could also be used to good advantage in the non-union systems, with even better results. Getting our technical people, trainees as well as experienced, to become enrolled in and to complete continuing education courses can be a problem. Everyone now seems to feel that training is beneficial to the employee and to the company, but few can agree on how to proceed.

One way that is being tried is by use of incentives. Again, the companies cannot agree on the best incentive plan. Listed below are three incentive plans that are in use.

a. Educational Assistance. This covers course prepayment and/or course cost reimbursement for employees who take job oriented courses from company approved schools. The amounts and procedures vary with each company.
b. Monetary Incentives. Some companies automatically increase their employee's salary by five (5) or six (6) cents per hour for each course completed with satisfactory grades. This doesn't sound like much, but it amounts to more than a hundred dollars each year for each course, in addition to normal pay increases. Other companies offer a one-time bonus for each course completed or license grade achieved.
c. Promotion Assurances. These companies promise promotions to course graduates, when and if openings occur. This is not a particularly good plan, since there is no immediate inducement to take or complete the course. Promotion from within the ranks should be standard procedure, not just as an inducement to study.

These are a few of the ways you can encourage your people to study. You should give a great deal of thought to setting up an incentive plan, if you don't presently have a good one.

One of my first assignments when I moved to Denver was to investigate and evaluate the available home study courses and to recommend the ones which would be of most benefit to our technical employees. After a lot of research and study, I don't really feel that there is any one "best" course for everyone. Each course studied has both good and bad points and there are needs and applications for each course. The real solution seems to be in correctly matching the employee to a course which is right for them. This means that you must be familiar with the employee's prior education, experience and also with their ambitions and expectations. In a small company, this is not a real problem but in the larger ones, it really is a challenge. To help me to become familiar with our employee's history and ambitions, I have come up with what I call an "Employee Profile Sheet." It is quite large so I didn't bring copies, but I will be happy to discuss it later with anyone who is interested or will send copies if you request them. In essence, it just gets some information about the employee that we can't get from personnel records. It can also be used to help determine when an employee is ready for promotion or transfer.

Those of you who have taken any kind of home study course are aware of the inherent problems in this type of education. In order to write a course of this type, the writer must assume that the student has absolutely no knowledge of anything technical. If that assumption is not made, at least part of the students will be left out, since they really are not technically knowledgeable. On the other hand, students who do have some electronics training or knowledge will be bored to the point of dropping out of the course. Selecting the proper course to match the student can help to overcome this problem.

The most frequent complaints that I get on home study courses are that they don't explain the lessons very well and that the math is too hard. These are all problems dealing with basic electronics. Once a student really understands the basic theory and the math fundamentals, we rarely hear another complaint. I have discussed this with representatives from the schools that we regularly use. Their suggestions have universally been to enroll the student in a good basic electronics night course at a local technical school before or during the home study course. This has proven to be an excellent method. The questions which arise during the home study course can usually be easily answered by the technical school teacher. There seems to be very little subject duplication, and what there is just helps to reinforce the students grasp of the subject.

For those of you who have people who wish to proceed onward to a BSEE degree, there is now a home study course which will help them to get it. It will require some resident school credits, but most communities have enough night classes either at a technical college or at high schools to cover these.

There are also a small but growing number of local technical schools which regularly offer a two year CATV course. With the success that these schools have in placing their graduate students into systems, better than 98% within 6 months after graduation, I think we can look for many more states to add CATV courses. As I understand it, their biggest problem is in getting qualified teachers who know and can teach all phases of CATV.

One way that you and I can help to bring up the quality of the education at the schools, and the numbers of such courses offered, is to volunteer our help as technical advisors. You will be amazed at how quickly the educators will accept and use your help and advice. You also get first pick of the graduate students.

There can be a problem with this. They may offer you a job as a CATV instructor. If you accept, we are right back where we started-looking for good, trained technical personnel.

I thank you.

FIGURE 4

SOME SAMPLE QUESTIONS AND THEIR "CORRECT" ANSWERS:

Q-1. Name three (3) types of cables used in CATV systems.

A-1. .750, .500 and .412
A-2. Aerial, underground and drop
A-3. Comm-Scope, Cerro and General
A-4. Air, Solid and Foam
A-5. Jacketed, bare, flooded
A-6. Small, medium and large

Q-2. What would you normally expect to find in a CATV "headend"?

A-1. Signals
A-2. Processors and modulators
A-3. Air Conditioner
A-4. Electronic equipment
A-5. Electrical equipment
A-6. Mice

Q-3. How can you determine if an antenna is bad?

A-1. By checking them out
A-2. By comparing them with a test antenna
A-3. By replacing them. If the new one works, the old one is bad.
A-4. If no signals come out when the TV station is on
A-5. I can't. I have never been taught how.
A-6. By climbing the tower or pole and testing them.

Are you starting to get the idea? Believe it or not, most of these answers have appeared on our tests. Legally, each of them is correct.

THE CHARACTERIZATION OF A VIDEO CODEC FOR CATV APPLICATION

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Abstract

The use of modern digital techniques is rapidly approaching a dominant role in the field of color television. An effective interface between the analog and digital worlds is of critical importance, and very often the quality of analog-to-digital (A/D) conversion is the primary limiting factor in overall system performance.

This paper describes a codec, consisting of an A/D Converter, a D/A Converter, and appropriate low-pass filters for application to digital CATV application. Emphasis is placed on the description of hardware, and the several parameters of particular interest in the color video field.

Test methods are described along with actual test results. These results indicate the very high level of performance achievable with this state-of-the-art hardware.

Introduction

Digital signal processing technology is having a tremendous impact on the television industry. Digital techniques are now being utilized in such broadcast and studio applications as time base correction, frame synchronization, standards conversion, on-line monitoring of television signals and image enhancement; and in such CATV applications as transmission from studio to transmitter, closed circuit industrial transmission, and combination video/telephone channel links. The increasing proliferation of these digital "black boxes" into areas which have been predominately analog has led to the definition of the term "codec". A block diagram of a typical digital device in its simplest form is shown in Figure 1. The term "codec" applies to the combination of a single A/D Converter followed by a single D/A Converter.

Various subjective tests such as those reported by Goldberg and others[5-7] have placed recommended sampling rates and resolution requirements on the video codec. It is generally agreed sampling at either three or four times the color subcarrier frequency is desirable. However, for some CATV applications, other sampling rates in the 10.74 to 18 MHz are dictated. For the NTSC composite video signal with a 3.58 MHz color subcarrier, the popular sampling frequencies are 10.74 MHz and 14.32 MHz, respectively. While the major emphasis of this paper will be on sampling at multiples of the NTSC subcarrier frequency, the concepts are equally applicable to other closely related sampling frequencies. Test results have also indicated that 8-bits of resolution are adequate for encoding the composite video signal without noticeable degradation. The present state-of-the-art in video codecs is 10 bits of resolution at sampling rates to 20 MHz.

The intention of this paper is to present methods which may be used to characterize such a codec in terms of parameters commonly measured by video test equipment. Test methods will be presented and characteristics peculiar to digital systems, as opposed to analog systems, will be discussed. A testing philosophy is developed which makes maximum use of existing video test equipment. The following characterization tests will be described:

- o DC Linearity and Accuracy
- o Bandwidth
- o AC Linearity
- o Signal-to-Noise Ratio
- o Differential Gain and Phase
- o 2T Pulse Response
- o 12T Modulated Sin^2 Pulse Response
- o Color Bar Response.

The practical characterization procedures presented should assist newcomers to digital video in evaluating A/D and D/A conversion equipment for use in CATV systems. The test results also indicate the high degree of performance that is achievable with properly designed state-of-the-art hardware.

Description of Eight-Bit Codec Hardware

A block diagram of the codec used in the tests described in this paper is shown in Figure 2. The input signal is passed through a 6.5 MHz low-pass filter to prevent aliasing errors when sampling at 14.32 MHz (four times the NTSC color subcarrier frequency). A similar filter is used on the D/A Converter output. These video low-pass filters provide a high degree of phase linearity throughout the passband. The test results presented in this paper apply primarily to 14.32 MHz sampling. For sampling at 10.74 MHz (three times the NTSC color subcarrier frequency), a lower cutoff frequency of about 5 MHz would be required to prevent aliasing errors. Similar test results are obtained for the 10.74 MHz case as are shown for 14.32 MHz sampling.

The A/D Converter utilized for these tests is the Computer Labs' MATV-0816, an 8-bit Converter capable of operating at sampling rates up to 16 MHz. (For sampling rates to 18 MHz, the CLI MOD-818 may be employed.)

The modular construction of the MATV-0816 A/D Converter is shown in Figure 3. The volume of this Converter is approximately 22 cubic inches, and the power dissipation is 10 watts. The MATV-0816 A/D Converter uses a combination of the serial Gray code technique and the all-parallel technique of A/D conversion. A block diagram of the converter is shown in Figure 4. The six most significant bits are derived from serial Gray encoders. Each Gray encoder is contained in a TO-8 integrated circuit package. The "residue" output of the sixth Gray encoder is applied to a 2-bit parallel encoder which derives the two least significant bits. The module is self-contained and includes an input buffer amplifier, track-and-hold amplifier, timing generator, and TTL-compatible output registers. The unit accepts the standard 0 to +1 Volt video input level at an input impedance of 75 ohms.

The D/A Converter used in the test codec is a Computer Labs' MDD-0820A modular deglitched D/A Converter. As shown in the block diagram of Figure 5, the D/A Converter contains an input register, 8-bit current output D/A Converter, deglitcher, output buffer amplifier, and necessary timing circuits. The output signal amplitude is the standard video level of 1 volt full scale into 75 ohms.

The source of encode command for the A/D Converter is derived from either the multiplied 3.58 MHz subcarrier output of the video test signal generator (for "locked" measurements) or from the adjustable 14.32 MHz crystal oscillator (for "unlocked" measurements).

A discussion of test methods and results follow in the next sections.

DC Linearity and Accuracy

The DC linearity error of a properly designed codec should be no more than ±1/2 of the weight of the least significant bit (LSB). This error may be in addition to the inherent ±1/2 LSB quantization error. Thus, the total error in the overall codec transfer function should not exceed ±1 LSB, or 2 LSB's peak-to-peak. However, the test results presented will show that properly designed video codecs can be expected to give considerably better performance.

The codec DC accuracy and DC linearity can be measured using the test setup shown in Figure 6. This test shows the codec errors due to encoding a 400 usec full scale ramp voltage input obtained from a standard function generator. The resulting error waveform provides a means of viewing the full scale DC performance of the codec. The difference amplifier may also be implemented by using two channels of a dual-trace oscilloscope in the "subtract" mode if care is taken not to overdrive either of the two inputs. Results for the test codec are presented in Figure 7. An ideal error waveform would have the characteristic 1 LSB peak-to-peak sawtooth waveform. If the combined accuracy and linearity specification of the codec is 0.2% of full scale ±1/2 LSB, then the error waveform should never encompass a band wider than 2 LSB's.

Note that the actual error waveform shown for the test codec in Figure 7 is well within this limit.

A video test signal which is particularly useful in evaluating codec linearity is available on some of the newer signal generators and is shown in Figure 8. This is known commonly as the "unmodulated ramp", and traverses the black-to-white level in 40 usec. The codec output can be observed on an oscilloscope for nonlinearities and missing codes. The dual-trace oscilloscope subtraction technique previously described can be utilized to check the actual error waveform. If the codec output is applied to a picture monitor, any step discontinuity in the codec transfer characteristic will appear as a vertical line on the screen. If the brightness level is adjusted on the monitor, any portion of the sawtooth can be examined. Incidentally, if the D/A Converter has signal-related "glitches" at the bit transition points, these will also be visible as vertical lines on the screen.

Bandwidth

The bandwidth of the NTSC color television is approximately 4.2 MHz.

In practice, color television signals contain little energy above 4 MHz.

The overall frequency response of the codec output follows a (sin X)/X curve. This is due to the reconstruction process in the D/A Converter, where the output can be considered a series of rectangular pulses whose width is equal to the reciprocal of the sampling frequency. When this pulse stream is applied to a low-pass filter, the attenuation at a frequency f with a sampling rate of f_s can be expressed as:

$$A_f = \frac{\sin\left(\frac{\pi f}{f_s}\right)}{\pi \frac{f}{f_s}}$$

This curve has been plotted in dB (Figure 9) for the cases of three and four times subcarrier sampling rates. Any bandwidth measurements on the codec must consider this theoretical rolloff unless compensation has been provided within the codec.

The "multiburst" test waveform is useful in making bandwidth measurements on video systems and is generally available on most video test signal generators. This waveform consists of a series of constant amplitude bursts at 0.5 MHz, 1.25 MHz, 2.0 MHz, 3.0 MHz, 3.58 MHz, and 4.1 MHz. More accurate frequency response characteristics can be obtained, of course, by input/output measurements with an oscillator and a RMS voltmeter.

The multiburst response of the test codec is shown in Figure 10 for a sampling rate of 14.32 MHz. Note that the 4.1 MHz burst is attenuated by about 14%, or 1.3 dB, as theory predicts.

AC Linearity

The ability of a codec to reproduce a spectrally pure sinewave is a measure of AC linearity. For an 8-bit system with a dynamic range of 48 dB, the signal-related harmonics should be at least 51 dB below full scale. In a sampled system, harmonics of the fundamental may show up as inband intermodulation products when they beat with the sampling frequency. For example, the third harmonic of a 3 MHz sinewave would appear at 9 MHz, and 5.32 MHz, for a system where the sample rate is 14.32 MHz. Note that the product at 5.32 MHz actually falls inside the video bandwidth.

Signal-related harmonics are greatly reduced by adding a "deglitcher" circuit in the D/A Converter (Figure 5). The deglitcher in the D/A Converter consists of a type of track-and-hold circuit which is placed in "hold" immediately before a new digital input word is applied to the D/A Converter current switches. The deglitcher track-and-hold remains in "hold" until the current switches have settled to their final value. When the switches have settled, the track-and-hold automatically returns to the "track" condition and slews to the new analog output established by the most recent digital input. In this way, the track-and-hold "masks out" the signal-related transients which occur at the bit transition points.

The effects of the deglitcher are seen in Figure 11(A), where the photograph shows a spectrum analyzer display of the codec output when a 1 MHz full scale sinewave is applied. The sampling rate is 14.32 MHz. Note the increase in harmonic content of Figure 11 (B), without the D/A deglitcher.

With no deglitching, excess noise is seen as vertical lines on the television screen when a black-to-white test ramp is encoded and reconstructed. These vertical lines appear where the ramp passes through the major bit transition regions. Figure 12 is a multiple exposure of an expanded portion of a digitized and reconstructed "unmodulated ramp" test signal. The left-hand trace is the output of a non-deglitched unfiltered D/A Converter. The center trace shows the effects of adding a low-pass filter to the D/A output. Note that the magnitude of the vertical glitches has been reduced; however, they are still apparent and have the same relative amplitude, and would be clearly visible on a picture monitor as vertical stripes. The right-hand trace shows the further improvement achieved by adding both a deglitcher and a low-pass filter.

Signal-to-Noise Ratio

A common method for measuring signal-to-noise ratio in analog video systems consists of measuring the amount of noise on the flat portion of a constant luminance test signal. Unfortunately, this test signal only exercises the codec if the peak value of the test signal is in the transition zone between two adjacent codes.

For digital systems, a full scale sinewave loading test has been developed which gives a better measure of the true signal-to-noise ratio. The test configuration is shown in Figure 13.

A "pure" full scale sinewave of about 500 KHz is processed by the codec. The level of the reconstructed sinewave is measured with the bandstop filter switched out. The bandstop filter is then switched in, removing the fundamental signal, and the RMS quantizing noise level is measured. For a perfect

N-bit codec with a full scale sinewave input, the theoretical RMS signal-to-noise ratio is (6N + 1.8) dB, or 49.8 dB for a perfect 8-bit system. The 8-bit codec under consideration measures within 2 dB of theoretical, or about 48 dB for the 500 KHz input signal. Tests have also been conducted using a 2.5 MHz input sinewave, and signal-to-noise ratios of about 46 dB are typical.

Differential Gain and Phase

Differential gain is defined as the percentage difference between the output amplitude of a small high-frequency sinewave at two stated levels of a low-frequency signal on which it is superimposed. Differential phase is the difference in the output phase of a small high-frequency sinewave at two stated levels of a low-frequency signal on which it is superimposed. Distortion-free processing of a color television signal requires that neither the amplitude nor the phase of the chrominance signal be significantly altered as a function of the associated luminance signal.

The most common test waveform used to measure differential gain and phase is shown in Figure 14 and is commonly referred to as the 10-step 20-IRE unit modulated staircase. Some of the newer video test signal generators have the capability of increasing the subcarrier amplitude to 40-IRE units. Another test waveform available on the newer equipment is shown in Figure 15 and is commonly called the 20-IRE unit modulated ramp. Again, the option is usually available to increase the subcarrier amplitude to 40-IRE units if desired. The system output being tested for differential gain and phase is usually measured on a vectorscope.

In a digital system, the standard 10-step 20-IRE unit modulated staircase test signal of Figure 14 will usually give misleading results on a vectorscope display of differential gain and phase, especially when sampling at a frequency locked to a multiple of the subcarrier frequency. Such a display is shown in Figure 16, where the differential gain is about 8% and the differential phase about 3^{o}. These numbers, while probably unacceptable for a strictly analog system, are very consistent with the theoretical analysis developed for an ideal 8-bit system.

As Felix[4] points out, the traditional assumption underlying the analog differential gain and phase measurement is that a differential gain error of 8%, for a 20-IRE unit signal, would introduce the same 8% error for an 80-IRE unit signal. This assumption is incorrect, however, in a digital system. The quantizing errors have fixed peak values regardless of the signal being quantized. The 8% reading on a 20-IRE unit signal due to quantizing would reduce to 2% on an 80-IRE unit signal and to 1.6% for an 100-IRE unit signal. There would be a corresponding reduction in the differential phase reading.

When making these measurements on a digital system, the objective should be to devise methods to "see through" the "spikes" on the display caused by quantization noise, and to observe the differential gain and phase error due to analog distortions.

The situation can be improved by several methods which will be illustrated by actual vectorscope displays of the 8-bit codec.

The three things which can be done to give a more meaningful measurement are: (1) Increase the subcarrier amplitude to 40-IRE units, (2) use the modulated ramp test waveform of Figure 15, and (3) "unlock" the sampling rate by about 100 Hz from an exact multiple of the color subcarrier frequency.

The effects of performing the above are illustrated in Figures 17 through 23. The method which is preferred is shown in Figure 23 for the case of the 40-IRE unit modulated ramp with unlocked sampling. The other results are presented for reference, however, to allow for all possible test waveforms. There are some cases where unlocked sampling is not practical, as in some CATV applications.

"2T" Pulse Response - "K" Factor

The 2T pulse has become widely accepted as a test signal to measure the short-time waveform distortion of a video signal. The 2T pulse consists of a sine-squared pulse with a half-amplitude duration of 2T. T is the transient time constant of the TV system and is defined as $T=1/(2 f_u)$ where f_u is the upper video-frequency limit of 4 MHz and T=0.125 usec. There is no energy in this pulse above the video bandwidth of 4.2 MHz. Therefore, the pulse should pass undistorted through an ideal video system.

Distortions of the 2T pulse such as ringing, smearing, etc., are normally analyzed in terms of K factors utilizing special oscilloscope graticules. Figure 24 shows the 2T pulse after processing by the test codec. There is practically no distortion, and the corresponding K factor would be less than 1%.

"12.5T" Modulated Sin^2 Pulse Response

The luminance and chrominance components of a color signal should pass through an ideal system with their relative amplitudes and delays unchanged.

variation in gain is called chrominance-to-luminance gain and variation in delay is called chrominance-to-luminance delay.

The modulated 12.5T pulse is often used to check thse parameters. Figure 25 shows this pulse after passing through the test codec. For a perfect system, the baseline should be flat. For the pulse in Figure 25, the baseline has a variation of 5% of peak amplitude. The shape of the baseline indicates there is no significant chrominance-to-luminance delay, but the 5% bend in the baseline indicates that the chrominance is attenuated by about 1 dB with respect to the luminance. This is exactly what is predicted by the (sin X)/X rolloff curve for four-times color subcarrier sampling (See Figure 9). Normally a high frequency "boost" circuit is incorporated in the system to compensate for this loss.

Color Bar Response

No testing program for a video codec would be complete without analyzing the codec response to a standard 75% amplitude full-field color bar test signal. A picture monitor is useful in analyzing color purity, and a vectorscope displays the color bars as individual vectors whose amplitude corresponds to the level of saturation and whose phase angle corresponds to the phase of the color with respect to the reference burst. The color bars should appear as distinct dots on the vectorscope screen and should fall within the calibrated squares on the graticule.

Figure 26 shows the vectorscope display obtained by applying the color bar signal to the test codec. For this measurement, the sampling frequency is "unlocked" from the multiple of the subcarrier frequency by about 100 Hz.

Summary

This paper has characterized an 8-bit codec in terms of test parameters of particular interest in CATV applications. The test results obtained in all cases indicate that the codec described is capable of meeting the particular demands of the video industry as a whole.

It is apparent the availability of this high performance hardware will attract more attention to the rapidly expanding area of digital television.

Acknowledgements

This technical paper was prepared as a supporting reference for a presentation at the 27th Annual National Cable Television Association Convention and Exposition on 2 May 1978. The following Computer Labs, Inc. associates have provided valuable contributions to the paper: W. A. Kester, W. J. Pratt.

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3. Bryan F. Smith, "High Speed A/D and D/A Converters: Their Effect on Video Signal Fidelity," Journees D' Electronique 1973; available from CLI upon request.

4. Michael O. Felix, "Differential Phase and Gain Measurements in Digital Video Signals," Journal SMPTE, 85: 76-79, February 1976.

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6. A. A. Goldberg, "PCM Encoded NTSC Color Television Subjective Tests," Journal SMPTE, 82: 649-654, August 1973.

7. Charles P. Ginsburg, "Report of the SMPTE Digital Television Study Group," Journal SMPTE, 85: 150-153, March 1976.

FIG. 1

BASIC ELEMENTS OF A DIGITAL DEVICE

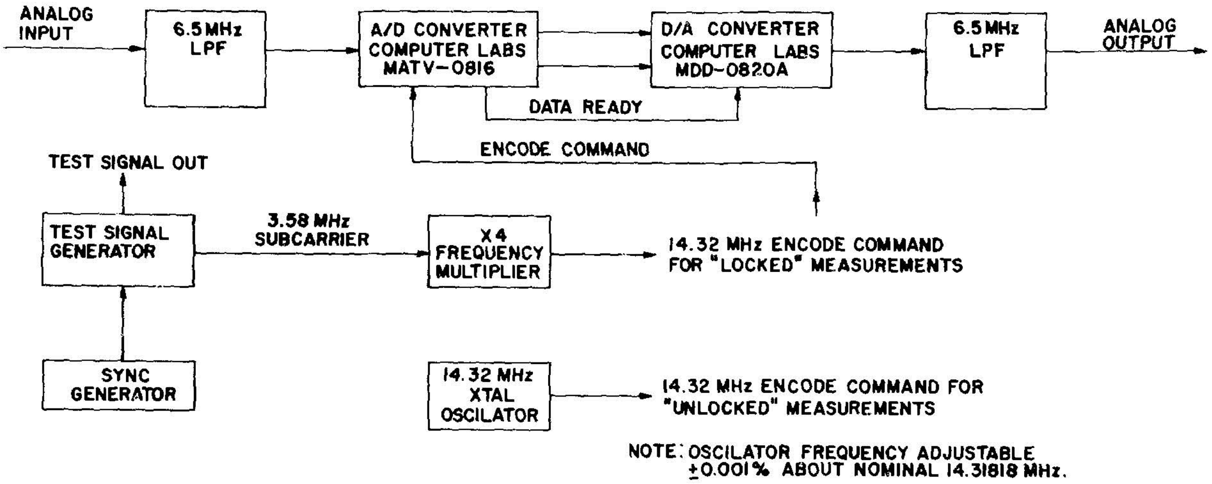
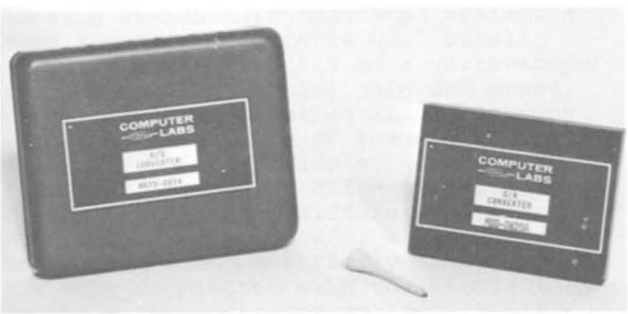
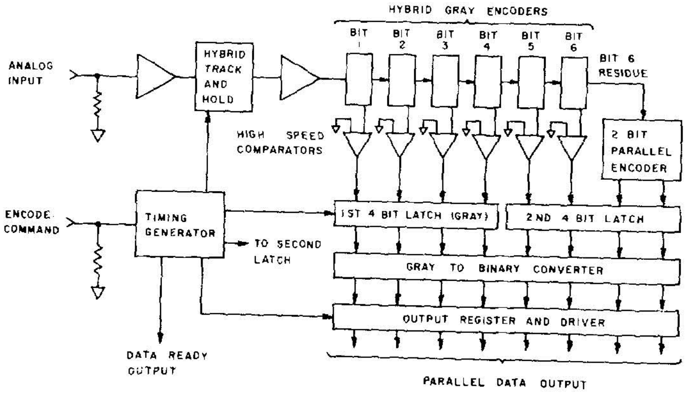


FIG. 2 CODEC BLOCK DIAGRAM





MATV SERIES A/D CONVERTER

FIG. 4

FIG. 3

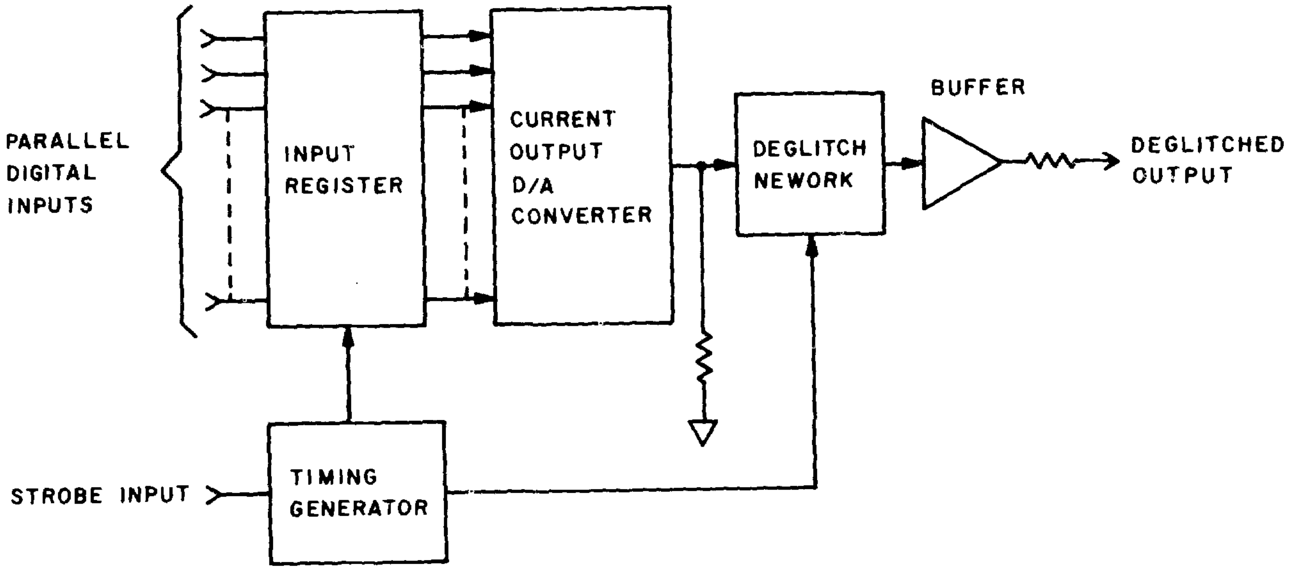


FIG. 5 **DEGLITCHED D/A CONVERTER**

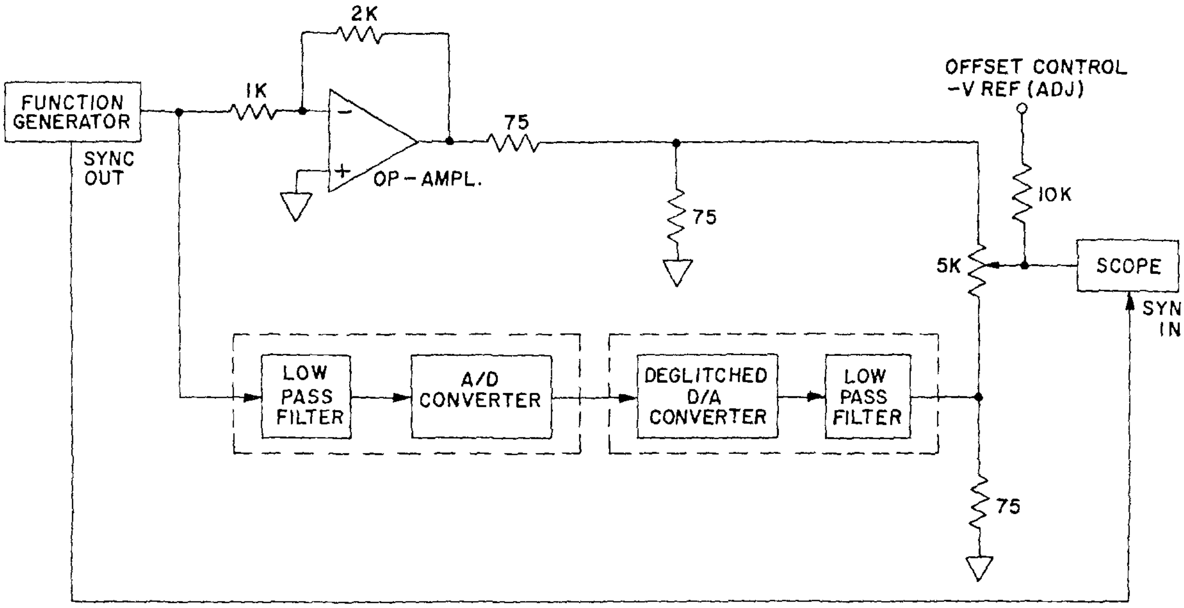
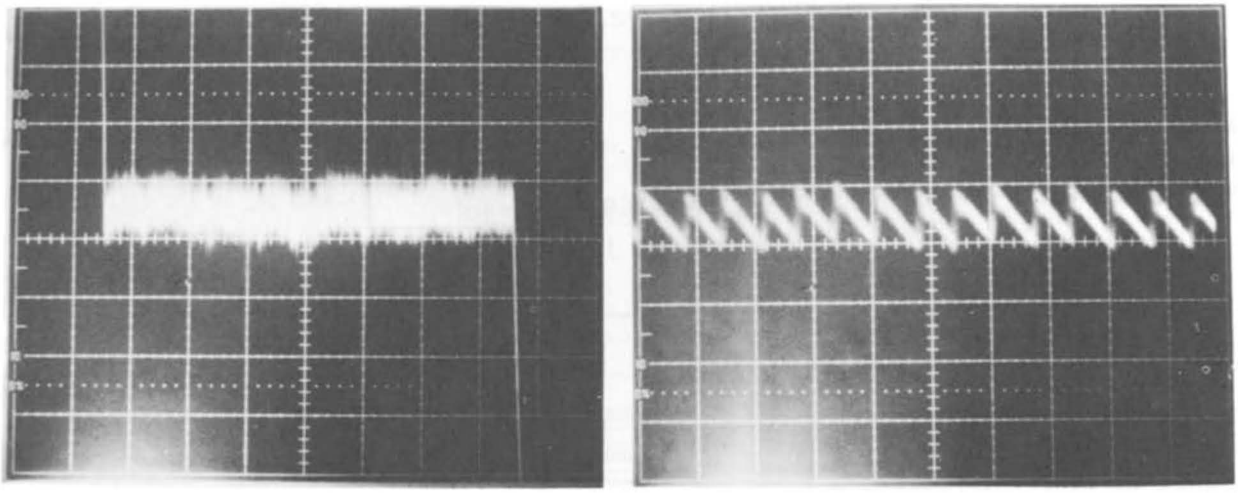


FIG. 6 RAMP LINEARITY TEST SETUP



(A) FULL RAMP ERROR DISPLAY
HORIZONTAL SCALE: 50 USEC/DIV.
VERTICAL SCALE: 1 LSB/DIV.

(B) EXPANDED DISPLAY
HORIZONTAL SCALE: 2 USEC/DIV.
VERTICAL SCALE: 1 LSB/DIV.

FIG. 7 RAMP LINEARITY DISPLAY FOR 400 USEC RAMP

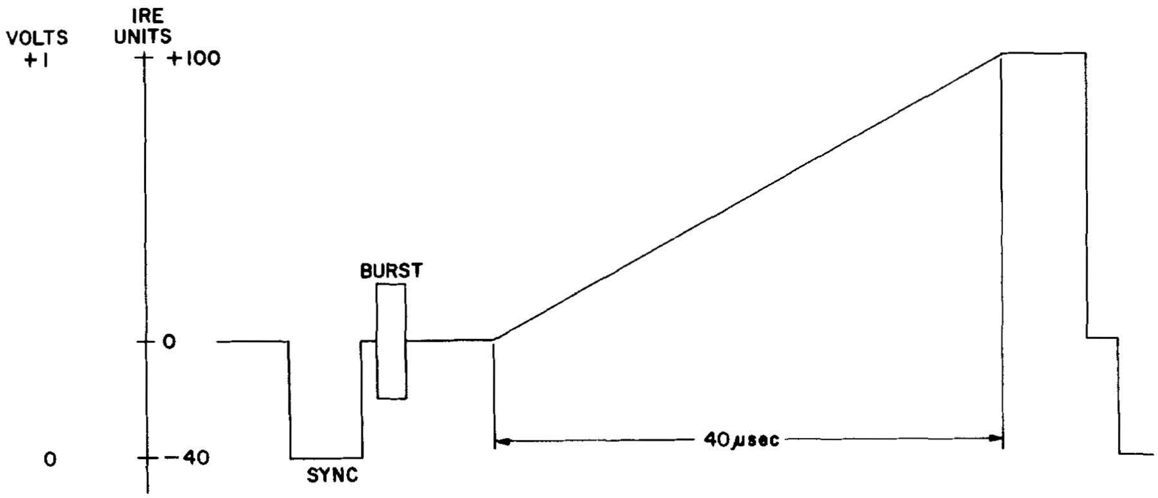
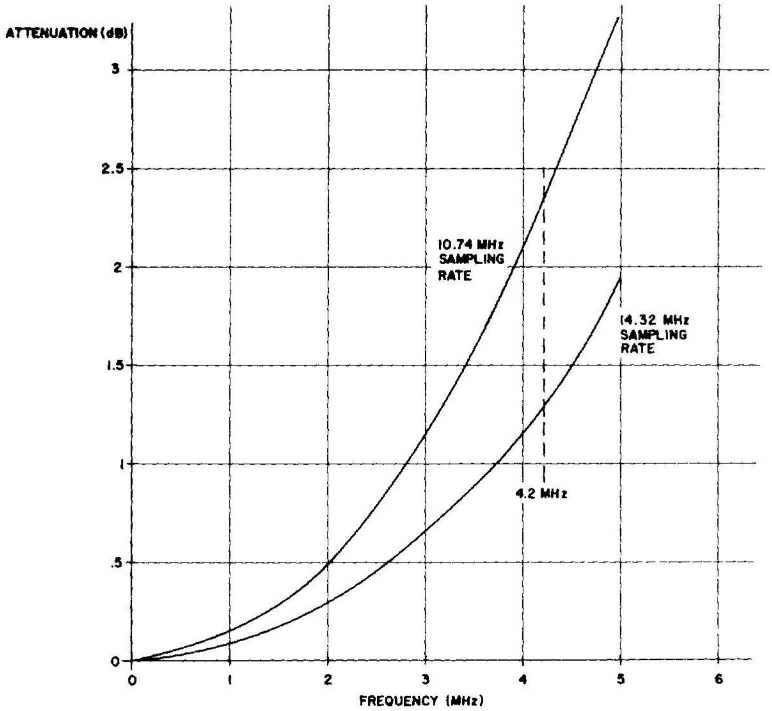
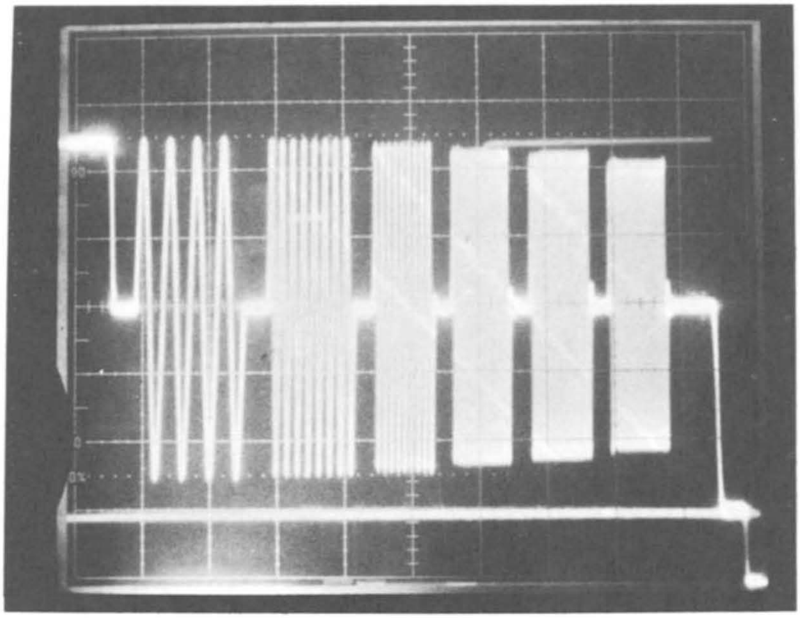


FIG. 8 LINEARITY TEST SIGNAL



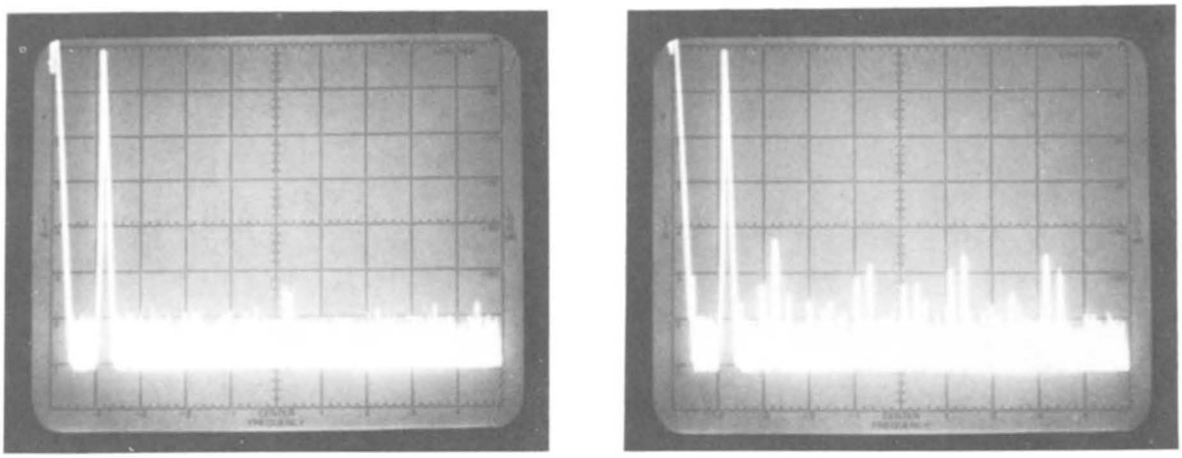
(SIN X)/X ROLLOFF IN dB

FIG. 9



CODEC MULTIBURST RESPONSE FOR
14.32 MHz SAMPLING RATE

FIG.10



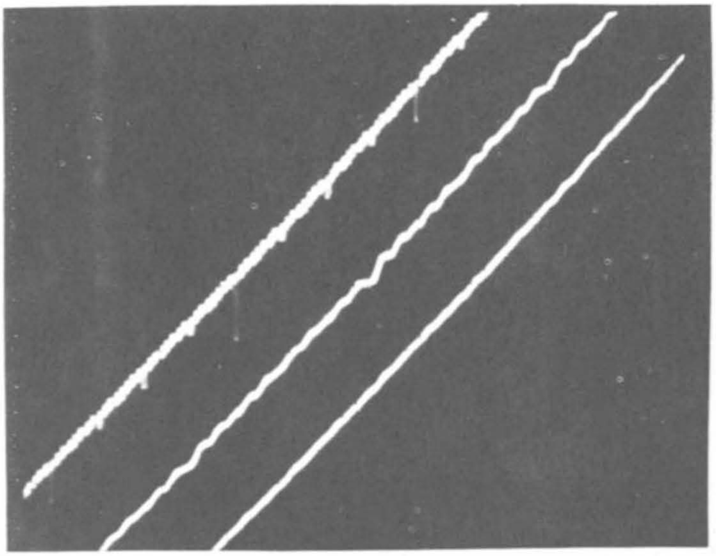
(A) WITH DEGLITCHING

(B) WITHOUT DEGLITCHING

SPECTRAL OUTPUT OF CODEC FOR 1 MHz FULL SCALE
INPUT SINEWAVE (NO OUTPUT FILTER)
SAMPLED AT 14.32 MHz RATE

FIG. 11

HORIZONTAL SCALE: 1 MHz/DIV.
VERTICAL SCALE: 10dB/DIV.



EFFECTS OF FILTERING AND DEGLITCHING ON
RAMP TEST SIGNAL

LEFT-HAND TRACE: NO FILTERING, NO DEGLITCHING.
MIDDLE TRACE: ADDITION OF 6.5 MHz LOW-PASS FILTER.
RIGHT-HAND TRACE: ADDITION OF DEGLITCHER AND 6.5 MHz LOW-PASS FILTER.

FIG. 12

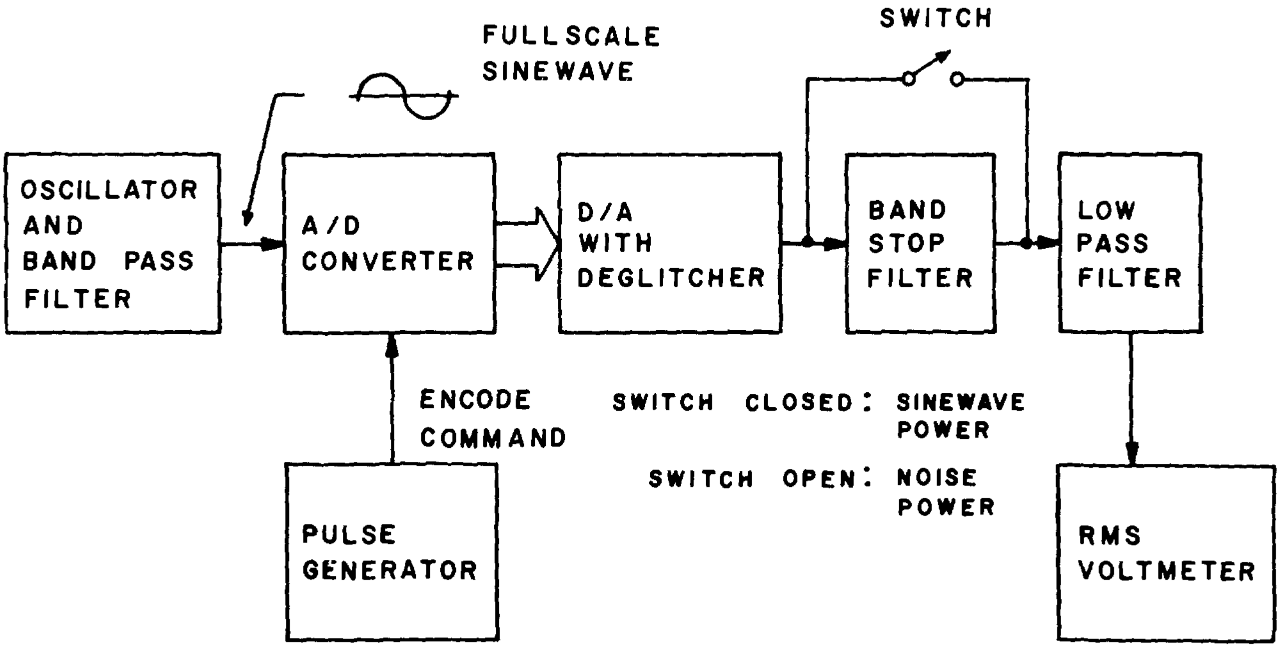


FIG. 13 **SIGNAL — TO — NOISE TEST SETUP**

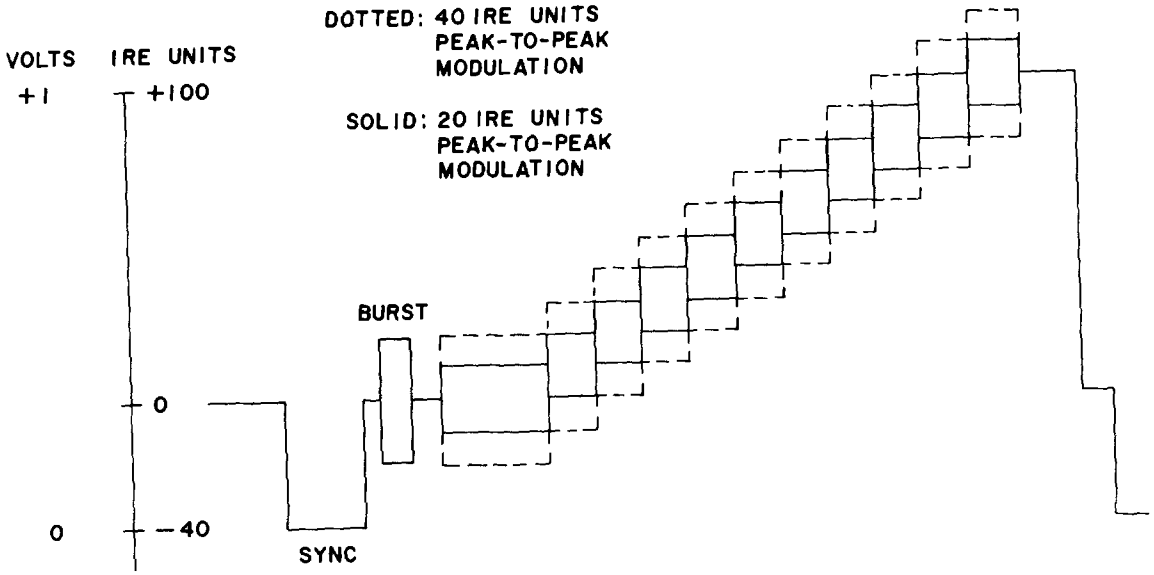
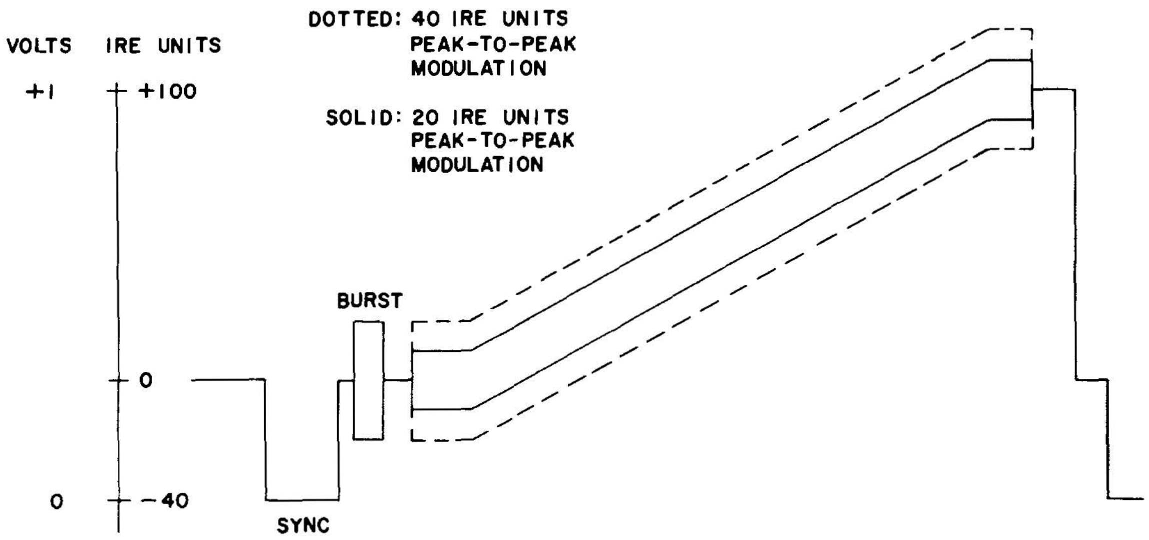
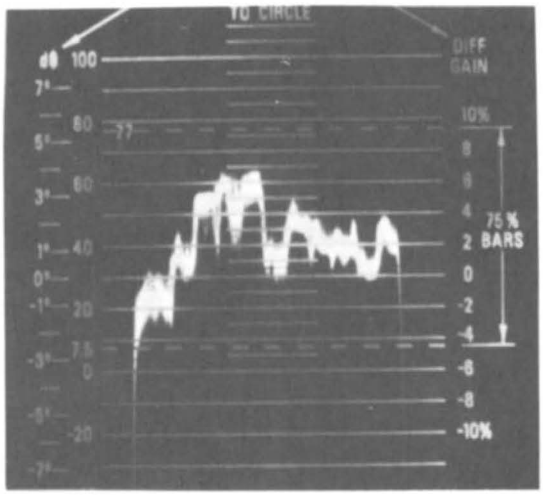


FIG. 14 10-STEP MODULATED STAIRCASE TEST SIGNAL

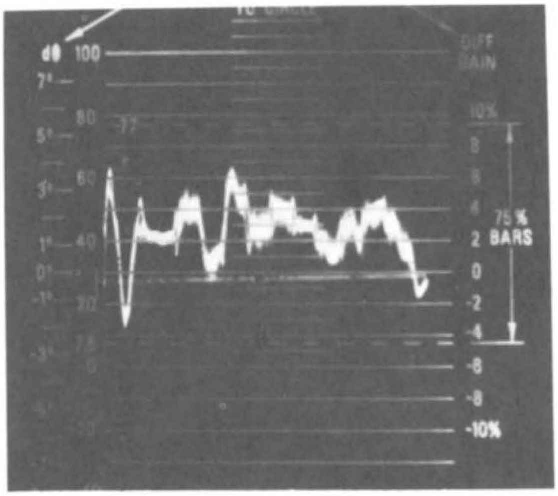


MODULATED RAMP TEST SIGNAL

FIG.15



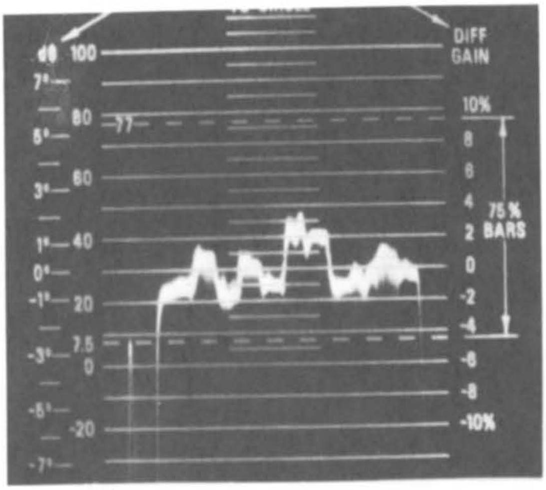
(A) DIFFERENTIAL GAIN



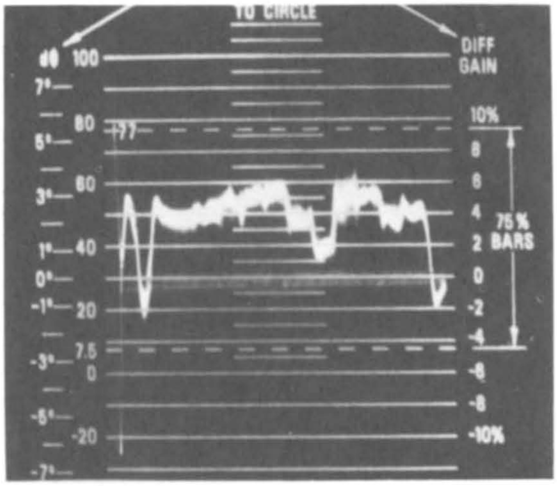
(B) DIFFERENTIAL PHASE

TYPICAL CODEC DIFFERENTIAL GAIN AND PHASE DISPLAY
FOR 10-STEP, 20-IRE MODULATED STAIRCASE TEST
WAVEFORM - LOCKED SAMPLING (14.32 MHz)

FIG. 16



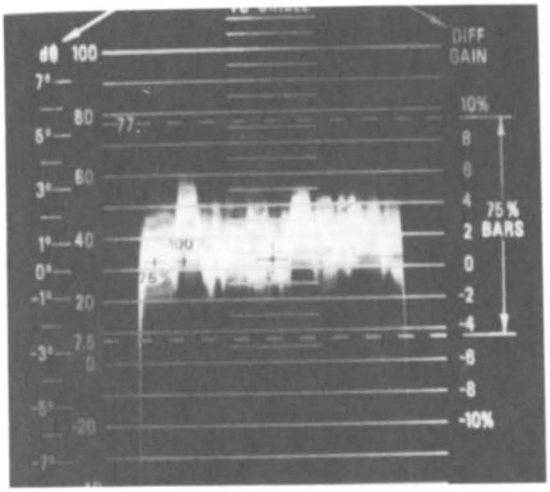
(A) DIFFERENTIAL GAIN



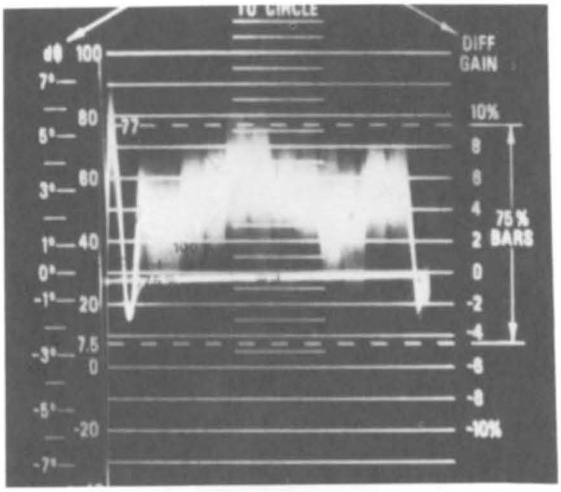
(B) DIFFERENTIAL PHASE

TYPICAL CODEC DIFFERENTIAL GAIN AND PHASE DISPLAY
FOR 10-STEP 40-IRE MODULATED STAIRCASE
TEST WAVEFORM - LOCKED SAMPLING (14.32 MHz)

FIG. 17



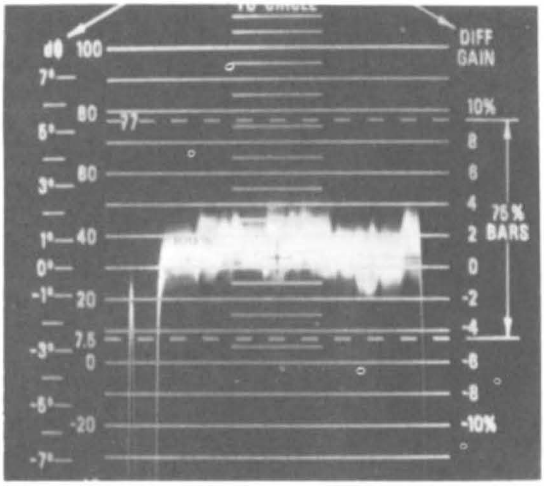
(A) DIFFERENTIAL GAIN



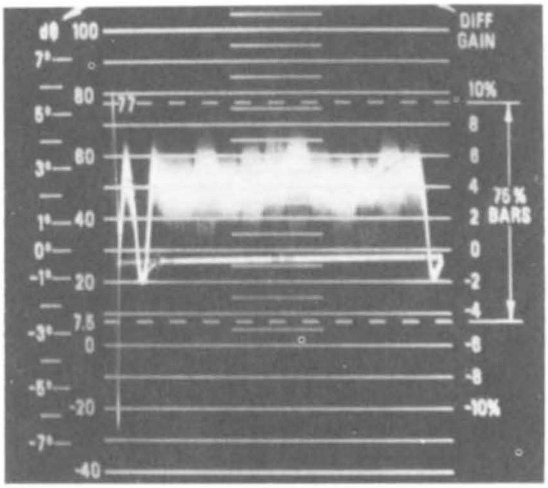
(B) DIFFERENTIAL PHASE

TYPICAL CODEC DIFFERENTIAL GAIN AND PHASE DISPLAY
FOR 10-STEP 20-IRE MODULATED STAIRCASE
TEST WAVEFORM - UNLOCKED SAMPLING (14.32 MHz + Δf)

FIG. 18



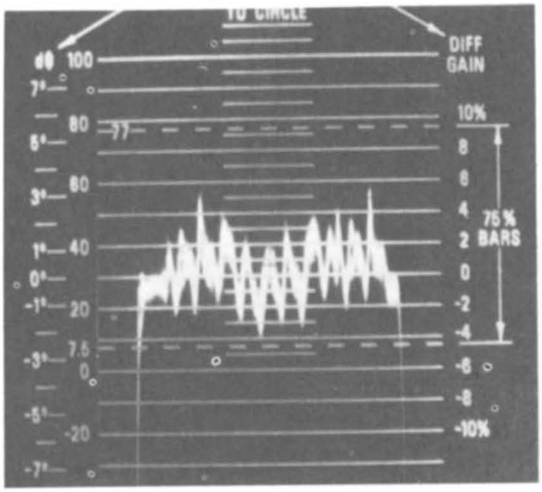
(A) DIFFERENTIAL GAIN



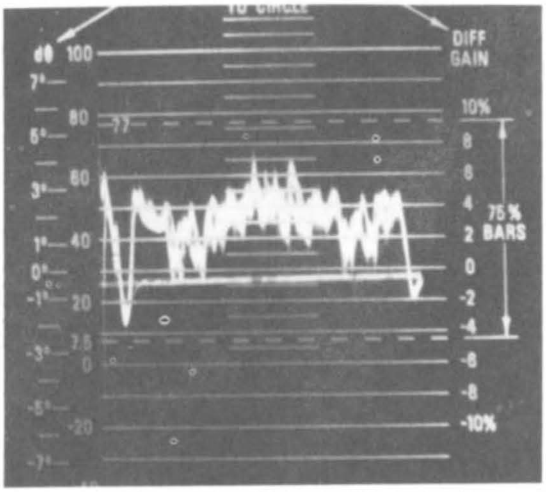
(B) DIFFERENTIAL PHASE

TYPICAL CODEC DIFFERENTIAL GAIN AND PHASE DISPLAY
FOR 10-STEP 40-IRE MODULATED STAIRCASE
TEST WAVEFORM - UNLOCKED SAMPLING (14.32 MHz + Δf)

FIG. 19



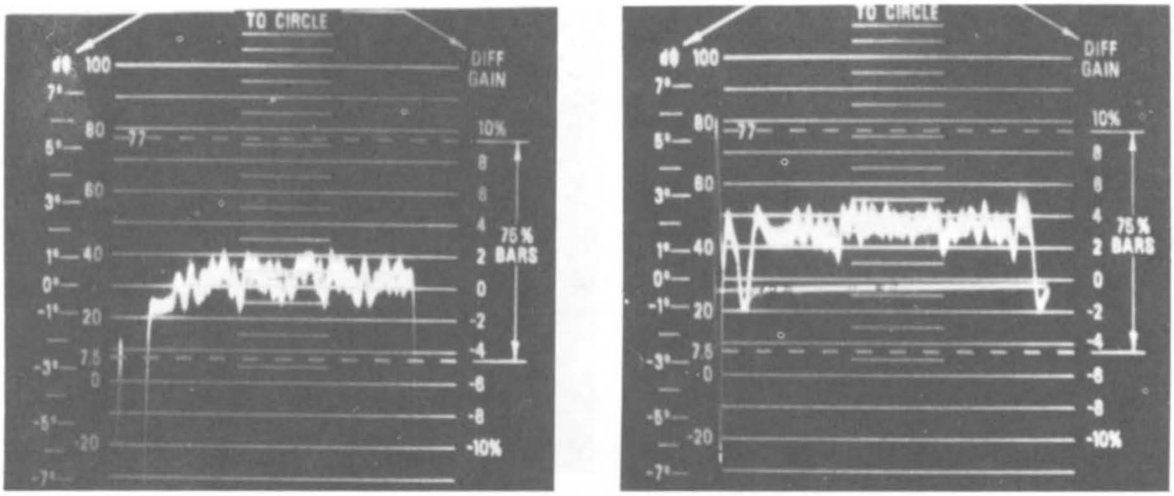
(A) DIFFERENTIAL GAIN



(B) DIFFERENTIAL PHASE

TYPICAL CODEC DIFFERENTIAL GAIN AND PHASE DISPLAY
FOR 20-IRE MODULATED RAMP TEST WAVEFORM -
LOCKED SAMPLING (14.32 MHz)

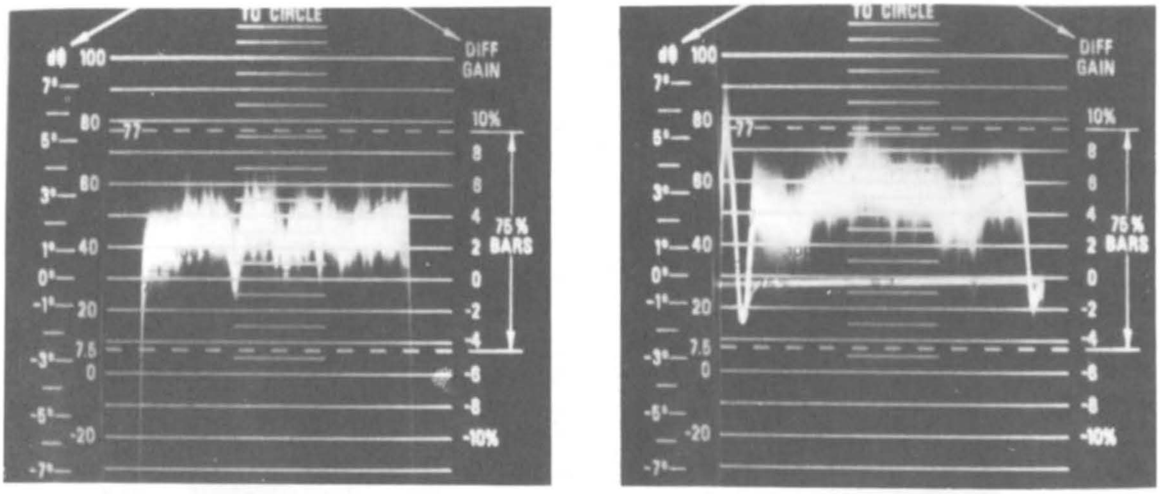
FIG. 20



(A) DIFFERENTIAL GAIN (B) DIFFERENTIAL PHASE

TYPICAL CODEC DIFFERENTIAL GAIN AND PHASE DISPLAY
FOR 40-IRE MODULATED RAMP TEST WAVEFORM
LOCKED SAMPLING (14.32 MHz)

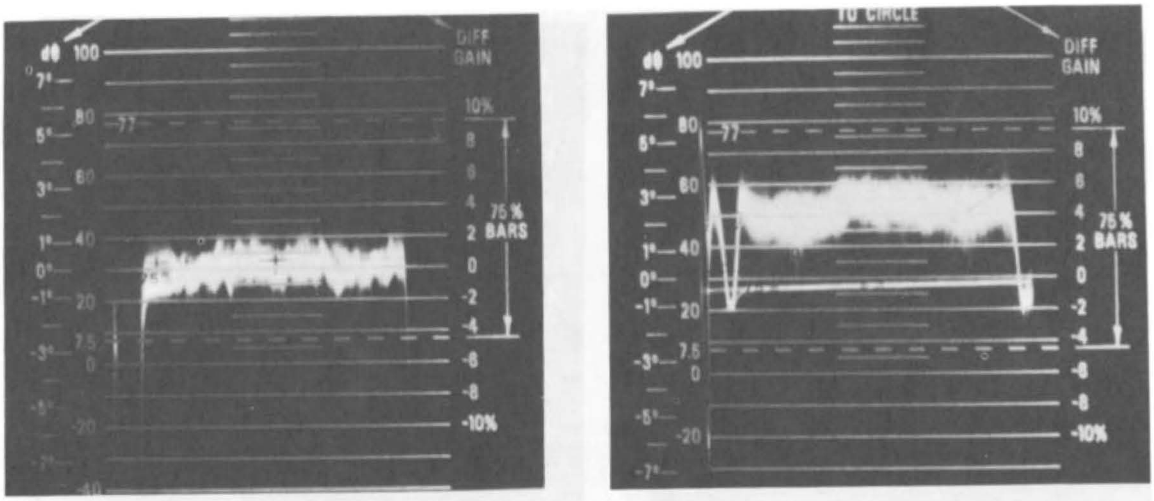
FIG. 21



(A) DIFFERENTIAL GAIN (B) DIFFERENTIAL PHASE

TYPICAL CODEC DIFFERENTIAL GAIN AND PHASE DISPLAY
FOR 20-IRE MODULATED RAMP TEST WAVEFORM
UNLOCKED SAMPLING (14.32 MHz +Δf)

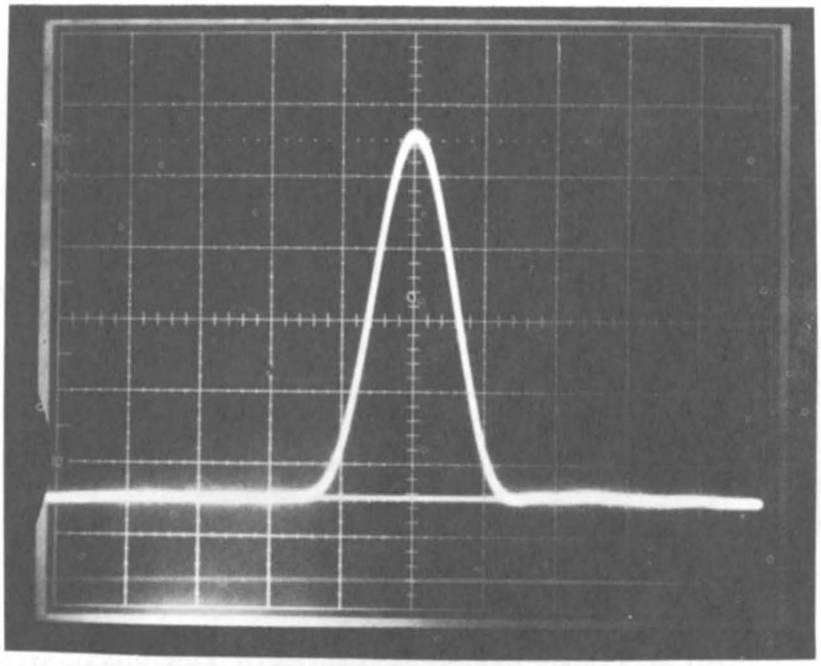
FIG. 22



(A) DIFFERENTIAL GAIN (B) DIFFERENTIAL PHASE

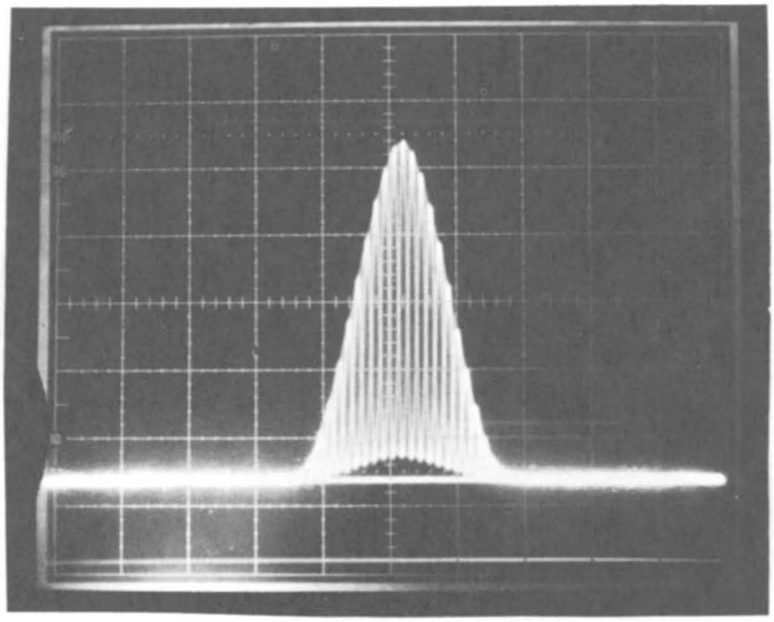
TYPICAL CODEC DIFFERENTIAL GAIN AND PHASE DISPLAY
FOR 40-IRE MODULATED RAMP TEST WAVEFORM
UNLOCKED SAMPLING (14.32 MHz + Δf)

FIG. 23



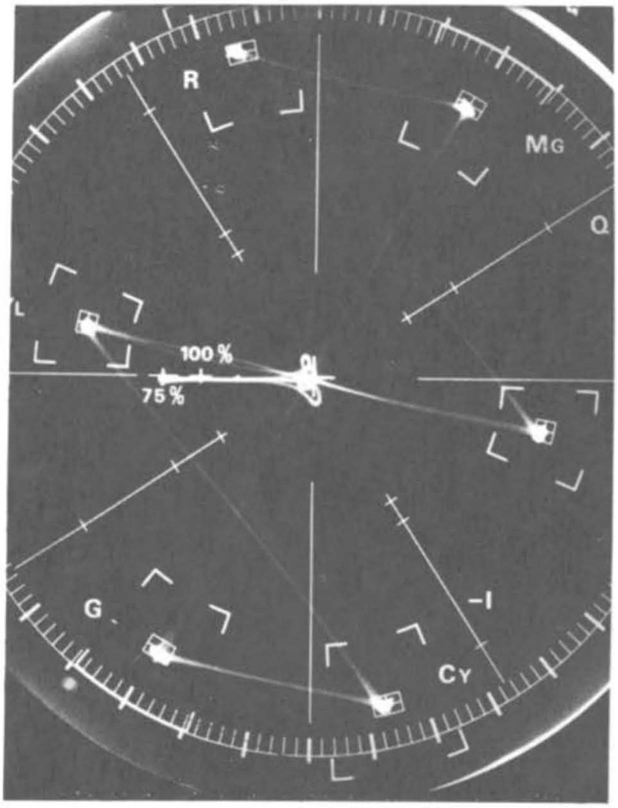
2T PULSE RESPONSE OF CODEC
HORIZONTAL SCALE: 200 NSEC/DIV.

FIG. 24



12.5T MODULATED SINE-SQUARED PULSE
RESPONSE OF CODEC FOR 14.32 MHz SAMPLING RATE
HORIZONTAL SCALE: 1 USEC/DIV.

FIG. 25



VECTORSCOPE DISPLAY OF CODEC
COLOR BAR RESPONSE - UNLOCKED
SAMPLING (14.32 MHz +△f)

FIG. 26

THE ROCKFORD TWO-WAY CABLE PROJECT: EXISTING AND PROJECTED TECHNOLOGY

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Michigan State University, East Lansing, Michigan
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ABSTRACT

As more systems investigate and implement the expansion of services via two-way cable, the need for a systematic approach to the development and deployment of this technology becomes apparent. This paper presents the four-generation model used in the development of the Michigan State University-National Science Foundation-Rockford Cablevision Two-Way Cable Project, concentrating on the first two generations of the plan which are currently operational in Rockford, Illinois. Significant space is devoted to a discussion of the initial cable system design philosophy, two-way cable system design precautions, experimental system operational design, spectrum assignment of services, return system operational levels, activation procedures of the return system, and finally maintenance of the plant. In addition to a discussion of the technology employed in the Rockford Project, a report on the performance of that technology is also presented. The upward expandability of the Rockford technology is discussed, with focus on the third generation prototype terminals now being developed to address utility automatic meter reading and load management energy problems.

INTRODUCTION

The most significant developments in two-way technology began in the early 1970's, when entrepreneurs such as Broadband Technologies (formerly Coaxial Scientific Corp.) developed and demonstrated the feasibility of two-way broadband cable communication. Broadband Technologies began by converting one of the four Columbus, Ohio, cable systems to two-way capability. A minicomputer was employed to scan the cable system, monitor and control four per-program pay-TV channels, and bill customers on a per-view basis.

Another example of both the technical and economic success of two-way broadband cable is found in the TOCOM, Inc., system serving Woodlands, Texas. Also one of the early innovators in two-way technology, the TOCOM systems provide for the monitoring of smoke detectors, security and medical alarms connected to subscriber-owned terminals. More recently, Warner Cable has announced the technical success of their new two-way system (QUBE), also in Columbus, Ohio. Finally, a number of other cities such as Dayton, Ohio, and Syracuse, New York, have expressed an active interest in the use of two-way cable for purposes of monitoring alarms.

Michigan State University became involved in the development of two-way cable technology in 1974, when it proposed using a two-way cable system in Rockford, Illinois, for training firefighters in pre-fire planning. In early 1975, MSU began working with the Rockford Fire Department on a video tape series to be used to instruct firefighters in the techniques of pre-fire planning. The proposal, funded by the National Science Foundation, called for four of the fire department's 11 stations to be wired into the two-way cable system to enable men in those stations to respond to questions presented on the video tapes via a modified (Jerrold SX-2) cable television converter.

Before becoming deeply involved in developing a new two-way system, MSU researchers decided to examine both the existing state of the art, as well as the future of two-way cable to determine the economic and technical viability of such a venture. In the past, the development of two-way systems has failed because the technology was isolated to a single service, and prevented major economies of scale through the multiplexing of applications for cost-sharing the two-way plant. Thus, a step-at-a-time approach was needed.

MSU researchers, Broadband Technologies, and Rockford Cablevision, conceived a four-generation evolutionary approach to the design, development and deployment of two-way technology over a variety of existing and potential services. Briefly, those four generations are as follows:

Generation I: The development of a combination Frequency and Time Division Multiplex (FDM/TDM) data collection system for two-way cable TV, where data is continuously transmitted from subscriber's terminal devices. Through the use of code operated switched deployed throughout the plant, it would be possible to control the return, or subband (upstream), signal from areas of the system which serve approximately 100 to 150 homes. From an operational standpoint, a computer at the headend would address a code operated switch, then direct a receiver in the computer to sequentially tune to each transmitter frequency and process the digital message from each household in that area. This process would be continued until all areas were surveyed by the computer. Applications of this technology would include per-program pay-TV, audience measurement, alarm and detector monitoring.

Generation II: The modification of the home terminal/converter to include a multi-position switch which allows the cable TV viewer a choice between the standard analog and new digital structure. Selection of the standard mode would render the terminal equivalent to its current analog logical function. When, however, a response channel is selected, the channel-selecting function of the terminal/converter is bypassed, and the television set is automatically tune to the appropriate channel. The selector keys can then be used to transmit digital data. Applications of this technology include interactive educational programming, public forum, consumer marketing questionnaires, etc.

Generation III: Development of the intelligent terminal via the introduction of a receiver logic circuit and microprocessor. As more and more applications are added to the two-way system, an efficient method must be found to handle the increased data flow. The receiver logic circuit allows the terminal to accept data from the headend, while the microprocessor would be programmed to control the data format. The increased flexibility of this stage allow such new applications as automatic meter reading and power load management, in-home shopping, complex questionnaires, video games, etc.

Generation IV: Currently the last projected stage provides for an increase in the information processing technology of the system through the addition of low cost "bubble" memory storage in either the terminal or in on-line logic gates such as the code operated switches. This will allow for the transmission of time-compressed digital signals to a memory in a specific location such as an individual subscriber terminal. With the increased data storage capacity, applications such as on-demand catalogs and newspapers would not be unlikely since it would be possible to "page" a portion of the downstream data channel for local display on the home television set.

The first two stages of the above four-generation plan are currently operational in Rockford, Illinois. The remainder of this paper will deal with some of the considerations involved in the design and deployment of that technology, as well as a discussion on the performance of the system to date.

DESIGN PHILOSOPHY

In our assessment of all the ills that beset the two-way cable system operator, both real and imagined, we drew a few personal conclusions from which the Rockford system design proceeded:

1. It is unlikely that there will be "a TV studio in every living room" due to (a) the limited need, and (b) the high cost.
2. It is equally unlikely that there will be a need for a audio communication circuit into the home as (a) the telephone adequately provides for this specialized need, and (b) the nature of a cable system is not conducive to such a service.
3. There is, or can be, a great deal of data collected from a home both to aid in the routine operation of that home, and to interconnect it with the active outside world (i.e., to provide it with an "interactive" capability).
4. There are a number of existing or potential video sources scattered around most communities.
5. There is a need for a local broadband distribution network for intracity data transmission to points scattered around the community.

If we consider the above list, and throw out the "blue sky" schemes, we arrive at a number of services which have a possibility of being sold, and which can be technically accommodated within the capabilities of a practical two-way cable television system.

We will discuss elsewhere in this paper specific system design problems and precautions. In considering these problems in conjunction with the several service applications listed above, a fundamental decision was made to use the system distribution "feeder" cables for data acquisition only, and to use the system transportation "trunk" cables, for remote video and business data acquisition. This decision permitted us to choose a system of feeder-return switching, under which the cable system is divided into small areas of about 150 addresses, and each is sequentially interrogated for its data content. As this data return signal is formatted as an FSK (FM) type of transmission and is narrow-band, it is unusually immune to the interferrence to which the distribution system is most susceptible. A 20 db signal-to-noise ratio provides an extremely reliable data circuit, and only occasional errors result to a 10 db ratio.

The switched data acquisition system chosen, developed by Broadband Technologies, was designed to operate in TV Channel T-7 (i.e., 5.75 to 11.75 MHz), and this suggested a further refinement of the cable system return path, limiting the feeder return bandwidth of this channel while keeping the trunk return at the full 5 to 30 MHz bandwidth. This was done with the overall result that no feeder return data or noise can be injected into the trunk return path except during interrogation, at which time the 12.5 to 30 MHz feeder noise contribution is attenuated by at least 25 db. This technique permits the trunk return, which has a relatively low "ingress" suseptability, to be maintained at "video quality" with respect to its signal-to-noise ratio.

DESIGN PRECAUTIONS

In anticipation of the then-known problem associated with two-way cable, Rockford Cablevision system designers were especially attentive to factors which could contribute to interference intrusion, or ingress, and would affect the upstream signals. Obviously the active and passive equipment selected for the system (e.g., amplifiers, directional couplers, tap-off units, power-insertion units, etc.) must have high RF shielding over the entire frequency spectrum, from well below 5 MHz to well above 300 MHz. A shielding effectiveness of 140 to 150 db would seem to be a minimum acceptable rating. Torque wrenches must be used in fastening covers and lids to maintain this shielding level.

Trunk and feeder cable fittings must have a similar shielding effectiveness, and this is accomplished in part by using the available steel cable-inserts. The fitting itself must seize and hold the cable so tightly that the two become as one with relative movement prevented. Too much pressure will result in metal deformation and "cold-flow", so here too it is most important that torque wrenches be used in tightening every fitting.

As a further precaution against fitting problems, the Rockford system uses two full-sized, flat-bottomed, expansion loops at each pole -- one on the span side of all equipment. This does provide more protection than necessary in preventing cable rupture due to flexing fatigue, however, at the same time, it virtually eliminates the forces on the fittings from cable flexing, twisting, expansion and vibration, and thereby removes the major cause of loose fittings.

Service drops are obviously the most difficult potential interference ingress source to control. First, because there may be twice as many miles of such cable as the combined miles of the whole distribution plant, second because system owners traditionally let up on standards at this point to cut costs, and finally because we are at the mercy of the subscriber after the cable enters the home.

Rockford selected the eight-mil bonded construction type of cable as the only one, at the time, which provided sufficient shielding at low cost. Long ferruled fittings using a hex crimpring were selected, and the cable was installed using loops which in this application were designed to prevent vibration from causing metal fatigue. At the grounding block, the eight-mil cable ended and a double-braded cable continued on to the wall plate and to the matching transformer. As a final effort toward minimizing ingress, TV matching transformers of the high-pass variety were selected, and in the case of 75 ohm television sets a separate high-pass filter was installed. These devices provide a low frequency rejection of 25 to 40 db reading from 30 to 5 MHz.

SYSTEM DESIGN

The Rockford system consists of studio/control devices at the cable system headend, primary code-operated switches (P-COS), secondary code-operated switches (S-COS), response terminals, and test end-of-line oscillators (ELO).

The Rockford system departs from usual system design philosophy in one important respect, the feeder cable upstream path passes only the 5 to 10.5 MHz spectrum while frequencies of 12.5 MHz and above are attenuated by 25 db or more. The trunk cable passes the full 5 to 30 MHz, which includes the feeder data signals. This feeder-cable bandwidth-limiting, together with the technique of feeder switching developed by Broadband Technologies, and quadrant switching, has brought signal and noise ingress, and system amplifier noise cascading down to very manageable levels.

The General Automation computer (SPC-16) listed in Figure 1, controls the various equipment in the studio so that lessons may be given and transmitted on TV Channel B with no human intervention. From an operational standpoint, the minicomputer is used to control a Shintron 367 time code reader/switcher, plus a time code controller designed and built by members of the MSU research group. The video tapes produced by MSU in cooperation with the Rockford Fire Department, were recorded with the Society of Motion Picture and Television Engineers (SMPTE) time code on channel one of a dual track video cassette. Thus, the computer can synchronize videotaped lessons with programmed computer instructions, starting and stopping the lessons based on the responses of firefighters on their remote terminals. The minicomputer interrogates the response terminals in the field by (1) transmitting coded FSK signals at 112 MHz to addressable receivers located in each primary (P-COS) and secondary (S-COS) code operated switch, which in turn determine the select upstream path and amplifier opened, and (2) by tuning one-by-one through the various COS, terminal, and ELO FSK signals, identifying each by the unique combination of frequencies, and reading the return data content. Thus, when a multiple choice question is presented on the video tape, the minicomputer will stop the lesson, interrogate the response terminals, and when all firefighters have answered, resume the lesson.

The headend quadrant return circuit control is shown in Figure 2. The primary code operated switch (P-COS) for each of the four quadrants is located within the cable headend, with only the North quadrant illustrated for purposes of this example. From an operational point of view, a firefighter at Fire Station #1 in the North quadrant might press a button on his modified SX-2 converter/terminal and enter his response to a multiple-choice question into the return data stream. This upstream signal, modulated at some specific frequency between 7.5 and 10.5 MHz, would be filtered through the diplexer shown in the diagram, and isolated by a 5 to 10.5 MHz low pass filter, and routed to a diode switch operated by the computer-controlled P-COS. A P-COS identifying tone is made to go through this switch as verification of its operation. All quadrant return diode switch outputs are brough together at a four-way mixer, with only one "on" at a time. After passing through a second (band pass) filter and an amplifier, the return signal is finally fed to the FSK scanning receiver at the minicomputer.

Figure 3 shows the basic two-way cable plant as used in this experiment and indicates its expo-

FIGURE 1: ROCKFORD CABLE HEADEND

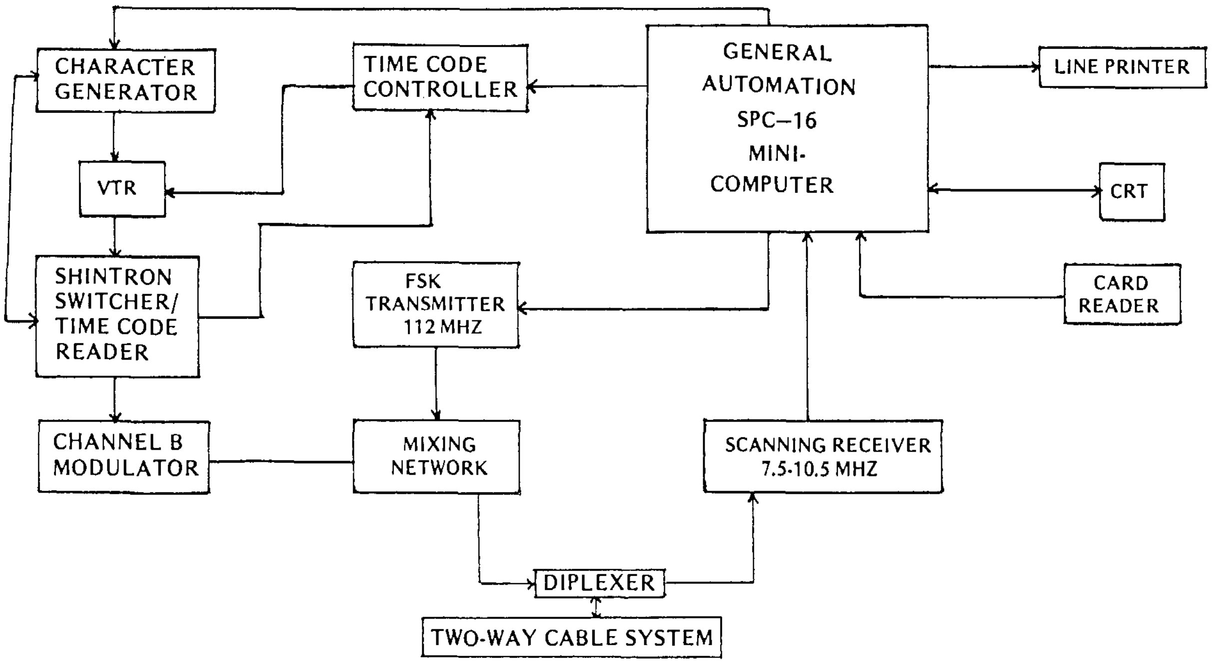


FIGURE 2: HEADEND QUADRANT RETURN CIRCUIT CONTROL

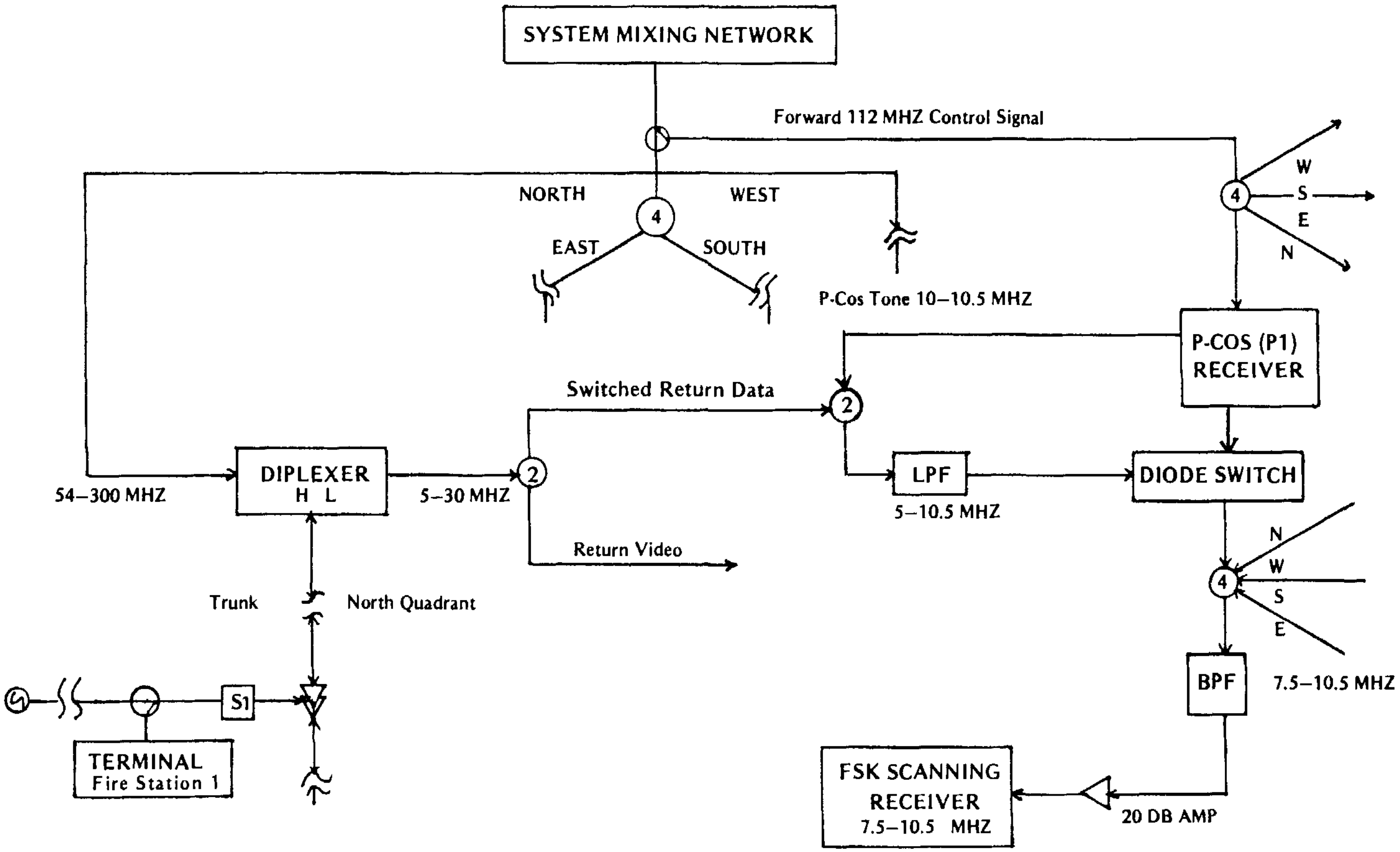
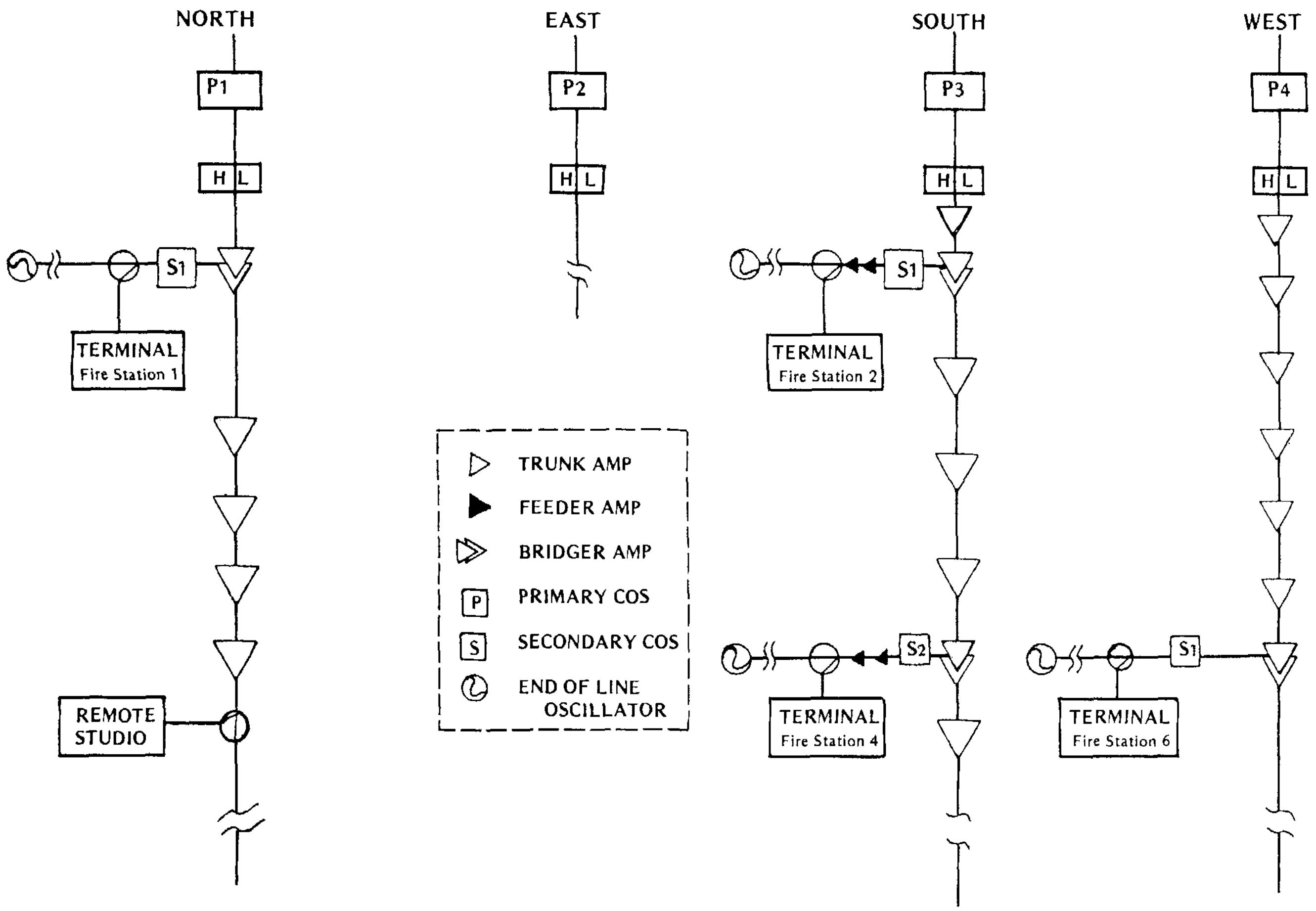


FIGURE 3: QUADRANT MULTIPLEXING



sure to ingress interference. At any instant of terminal interrogation, about 4,000 feet of feeder cable, 9,000 feet of trunk cable, and 15,000 feet of subscriber service cable (e.g., 40 subscribers) is "on" and is a potential source of short-wave radio or electrical interference.

In this experiment the feeder cable and subscribers-per-amplifier is low due to the turning-up of only enough amplifiers to effect the desired return path. A normal fully operational amplifier would have about 8,000 feet of feeder and 65 subscribers with an ingress-exposure factor about twice as great.

The terminal houses an FSK transmitter which is "on" all the time and which is modulated by activating any of several push-buttons on the modified Jerrold SK-2 converter. This causes a data word, which is also continuously transmitted, to change its content accordingly. The ELO is a test signal transmitter located as its name implies, at the end of the line. Initially this signal was simply monitored for its presence and amplitude, however newer units will be used shortly that have a forward signal monitoring capability so that total plant maintenance will be greatly improved.

The amplifier and S-COS configuration used in Rockford is shown in Figure 4. A Magnavox 4-MC-2 series amplifier was factory modified to (1) limit the feeder return to the 5 to 10.5 MHz frequency band, and (2) include a feeder return disable capability which is accessed through the amplifier's unused 7th port. A modified COS incorporates the FSK receiver and addressable logic which provides the control voltage to the feeder return switch. This S-COS also injects a special frequency into the return path which functions for test and identification purposes.

OPERATIONAL LEVELS

The manufacturer specifications for upstream television signals call for return amplifier output levels of +30 dbmv for four channels. This level generates extremely low intermodulation products and, in our system of switched feeders, results in an intrinsic signal-to-noise ratio of about 50 db. A change in level setting techniques should be mentioned here, in which one uses the return amplifier inputs as the equalization and control point rather than the amplifier outputs as in normal forward transmission. This is mandated by the multiplicity of signal sources all arriving at the amplifier by different paths with random lengths and attenuations.

The +30 dbmv television signal was used as the starting point and four such signals accepted as the desired amplifier loading. By assuming a 9 db gain as required for a "worse case" situation, an amplifier input of +21 dbmv for television becomes the specified level for the television signal trunk return amplifier inputs.

Assuming a 10 KHz data signal bandwith, and a 10 KHz guardband, the 4 MHz television channel will accommodate 200 such data channels. By operating these 200 channels at -2 dbmv (amplifier input), we load the amplifier approximately as heavily as one television channel at +21 dbmv, and this then becomes the specified level for a 10 KHz data-signal trunk return amplifier input. Line extender amplifiers are operated at a +1 dbmv input, based on the output capabilities of the various signal sources and system losses.

From these input levels we may determine the maximum permissable interference levels for each of the types of noise with which we must contend. Table I below indicates various interference levels measured over the two types of service, television and data.

Table I: Interference Levels by Type of Service

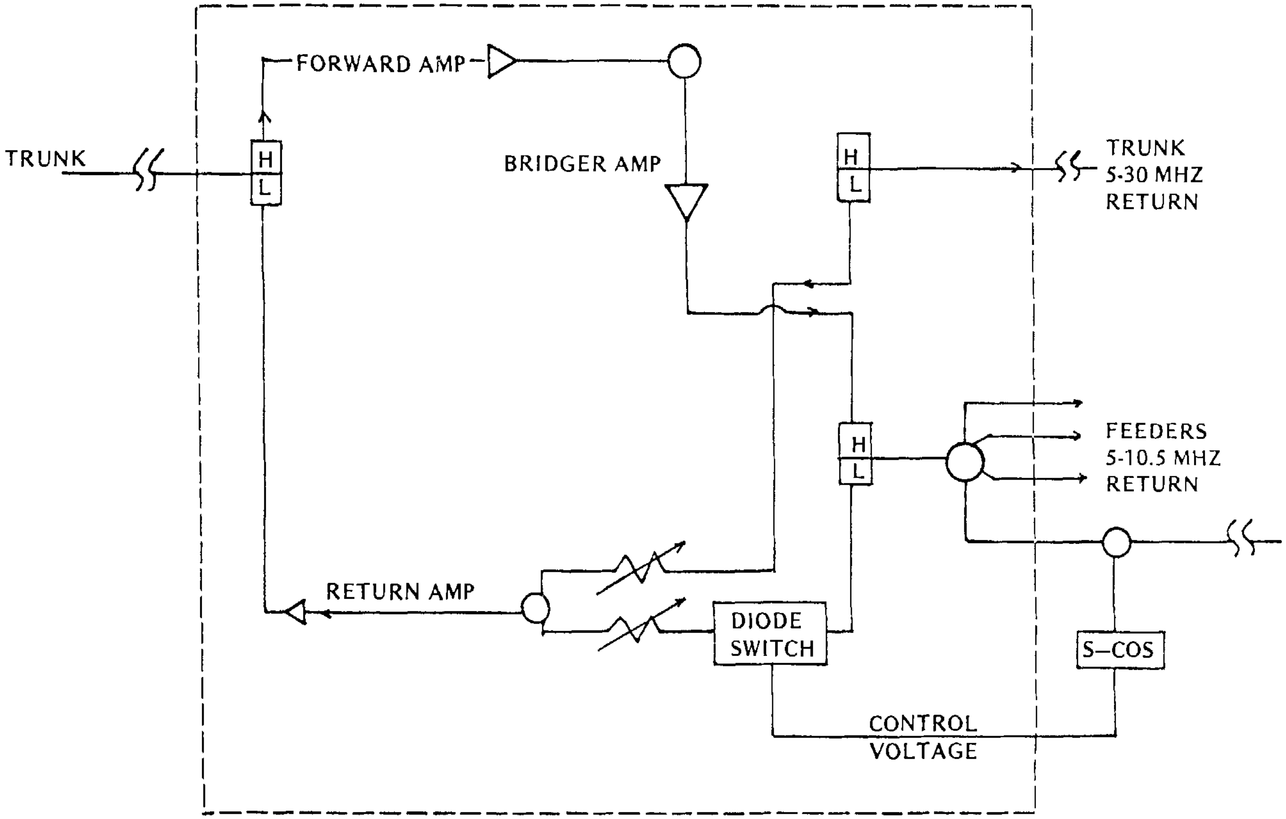
Type of Service	Trunk Amplifier Input Level (dbmv)	Random Noise (dbmv)	Discrete Radio Signals (dbmv)	Electrical Noise (dbmv)
Television 4 MHz	+21	-26	-36	-25
Data 10 KHz	- 2	-22	-22	-22

As the nuisance value of the interference is frequency related, it is necessary to list the Rockford Cablevision frequency assignments for its return system. In Table II below, the spectrum allocation of the upstream portion of the system is indicated.

Table II: Upstream Spectrum Allocation by Type of Service

Type of Service	Frequency Allocation From	To
Data Acquisition	7.5 MHz	10.5 MHz
Voice, System Alarms	5 MHz	7.5 MHz
Television	11.75MHz	23.75 MHz
Business Data	23.75MHz	30 MHz

FIGURE 4: COS/AMPLIFIER STATION



While indicated as a separate service in Table II, it should be noted that "voice" is used only in conjunction with the remote television service on trunk lines. Note also that the business data band will avoid the CB band at 27 MHz. Random noise, as an interference, is dealt with in system design and will be no problem whatever for data if it satisfies the requirements of the television service.

Discrete radio interference is a major problem in the 5 to 15 MHz band, and again at 26.96 to 27.41 MHz (e.g., CB). While FSK data and FM voice systems can tolerate interference ratios of 10 db, even up to 4 db, we have found that we have no problem holding this interference to at least the 10 db ratio and normally to a 20 db or greater ratio. Within the television channels used, T-8 and T-9, the only problem area is the 13 to 15 MHz range, and here again we are able to achieve the desired -36 dbmv (-57 db ratio) with reasonable maintenance measures due to essentially trunk-only exposure. The CB interference problem was nearly uncontrollable, and the goal became a two-fold one of avoiding the use of these frequencies, and of containing them to the extent of preventing them from contributing significant loading to the return system. This abondonment of the CB frequencies meant that television channel T-10 could not be used for television, and we have therefore assigned the resulting split-band to the business-data service.

Electrical interference, at -22 dbmv measured at 10 KHz bandwidth for data, or at -25 dbmv calculated to a 4 MHz bandwidth for television, does not pose a serious problem. The greatest exposure area, the feeder cables, are able to tolerate the highest interference level in the system, and conversely, where we need the best protection at the trunk television frequencies, we are the most protected. The business data band has no problem in that by the time we achieve the necessary interference ratios for television we are 20 to 30 db beyond the needs of a data circuit.

MAINTENANCE PROCEDURES

Initial set-up of the cable system return transmission path is accomplished by inserting a composite test signal (at 6, 9, 19 and 28 MHz) into the input of the last return amplifier (e.g., first forward amplifier) with all frequencies at the same arbitrary, let's say -2 dbmv, level. The display at the headend is monitored and the amplifier gain and slope controls are varied to achieve a flat display of an amplitude consistent with the losses built-in between the amplifier and the test point. This flat display is logged and the field person then moves back to the next amplifier and repeats the procedure and adjusts for the same display. This procedure is repeated back to the first return amplifier. A technique is being developed to allow the field man to carry a small TV set and to remotely observe the head-end display on command. Initially, all remote signal sources, such as terminals, ELO's, TV modulators, etc., must be set up using a two man team to insure that the amplifier input signals are properly balanced. The remote-controlled monitoring will serve this operational need as well as for initial set-up.

Signal intrusion into the return path of a cable system is directly related to signal radiation by the forward system. The nature of the system defect will determine the magnitude of both the signal ingress and egress, as does the frequency of the signal involved. The first step we follow in "de-ingressing" is to carefully monitor the involved area with a "Sniffer" (Com Sonics) and to correct any observed radiation down to a level usually somewhat below the FCC radiation limits. After this a technician moves one amplifier at a time, feeder by feeder, tap by tap, and drop by drop as necessary, until the ingress is some 10 db better than the minimums. This procedure results in a rigorous testing of the overall integrity of the return cable plant, excluding the forward amplifiers, and will reveal many problems that are only marginally, if at all, apparent on the forward side of the system. A welcome end-result of de-ingressing is better performance on the forward system. The Rockford experience is that once you go through de-ingressing, the results are long-term.

UPWARD EXPANDABILITY

The discussion up to this point relates to the implementation of the first two stages in the four-generation model. The MSU-NSF-Rockford Two-Way Cable Project, as a technical operation and from a cable operators standpoint, was an unqualified success. In a nutshell, after an initial period of de-ingressing the system, and of technician training, the experiment proceeded, and continues to proceed, with virtually no special maintenance attention and only nominal technical monitoring of the return signal levels and signal-to-noise ratios.

Adaptation of the Rockford system to the third generation of the plan would require minimum change. Initially, the FSK transmitter circuitry would be placed in a separate terminal box. Since requirements of the third generation dictate the terminal also have the capability to "receive" messages and act upon them, a receiver logic circuit is added to handle incoming messages. Control of these functions is accomplished via a microprocessor within the terminal. A prototype third generation terminal is currently being developed at MSU. The evolution of the system beyond the third generation is a point of speculation due to always-changing technology.

CONCLUSION

Perhaps the most important point of this paper was to demonstrate the success of the first two stages of the four-generation model, and the two-way technology employed in Rockford to date. No longer are system operators required to make a gigantic leap into two-way, testing the water with both feet. As indicated in this paper, a step-by-step approach is not only technically feasible, but cost-effective with new services added on a demand basis. In a capital-intensive industry, the upward expandability of new technologies must receive primary attention.

THE URBAN MARKET: PAVING THE WAY FOR TWO-WAY TELECOMMUNICATIONS

John D. Fannetti & Jack Reed

City of Syracuse

The City of Syracuse, by reason of its recent decision in favor of a sophisticated two-way cable system with the capability of delivering both entertainment and services to its subscribers, has become at once a testing ground for the application of this totally new concept to the major urban market.

All indications are that the future growth and, perhaps the very survival, of the cable industry will rely heavily on its willingness to accept the challenge to be responsive to the ever-increasing needs of the subscriber, particularly the urban dweller. The cities of the nation, by the very nature of their populous composition, are the obvious choice for a two-way telecommunication system capable of fulfilling these needs, while at the same time providing the cable operator a good rate of return on his investment.

While the earlier consensus was that cost would be a prohibitive factor in considering the delivery of services, even should the idea prove technically feasible, there has been a reversal on this theory. The idea has proven technically feasible, and marketing surveys have indicated that the cost factor will be a positive rather than a negative consideration, even with a conservative rate of penetration. This means that the provision of extensive services to the urban subscriber need not -- in fact, will not -- diminish the market's attractive financial outlook, but will, rather, enhance it, thus making the major urban market an attractive one, indeed, to an increasing number of cable operators.

But how can success be insured in such an innovative venture? And what are the necessary steps and precautions that must be taken to make such an undertaking economically and practically feasible?

Using the City of Syracuse as a model, this presentation will explore the various stages in the development of a total two-way cable system, particularly as it applies to the urban market. In so doing, we will examine the criteria that has thus far been, and continues to be established, as the system envisioned for Syracuse now enters the realm of reality.

Before commencing, it should be stressed very strongly at this point that such a system must be designed specifically and uniquely for that particular area or market it will serve. This will entail considerable pre-engineering, to ensure the avoidance of the problems and ptifalls previously encountered in efforts to provide municipalities with a two-way communications system.

Analyzing and determing the ideal concept which might yield the ultimate CATV system relevant to performance, flexibility, reliability, expandability, economical and marketing feasibility is indubitably a Herculean task. It's significance of importance is second to none in the preliminary ground rules set forth for attaining the aggregate requirements of any cable system.

In many instances, the geographic limitations within a community will indicate the appropriate system concept. Specifications for performance criteria might also constrain the number of potential design techniques.

System "concept", in this sense, does not involve determining the provisions for number of channels, distortion parameters, subscriber performance specifications, municipal/private access, pay TV, etc., but a means of delivering these predetermined specifications and services in the most efficient manner.

Geography without a doubt plays a powerful role in determining the concept of a cable plant. Its existence is, in fact, suggestive. Master-Headend, Master-Hub, Sub-Headend, Slave Hub, Microwave, Mid-Split Interconnect, Long-Haul Transportation, these familiar configurations are typically pertinent to geographic limitations. What is ideal for the City of Syracuse.

Long-Haul, Microwave, and Interconnecting Hubs are commonplace in an abundance of urban markets. This precedence is primarily due to the magnitude of these markets. When is a Hub-type system, regardless of interconnect design, most applicable? A Hub-type system is necessary when:

A. The overall distance from one central distribution point to the extremities of the system produces a cascade (the number of mainline amplifiers in succession) of such proportion that end system performance becomes electrically unattainable.

B. The total number of amplifiers exceeds the tolerable limit of "noise funneling" (the combining distortion effect in the return path of a bi-directional system). A Hub-type system essentially divides the total number of amplifiers by a factor equal to the number of hubs.

C. Environmental boundaries such as rivers and lakes or man-made structures such as railroads or superhighways, obstruct or eliminate a convenient path for an economical distribution system via direct cable path.

D. Restrictions within the community (school districts, political districts, etc.) dictate proportioning of the cable plant.

These four points represent only a few examples, but they are the most influential variables in evaluating the ideal concept for the City of Syracuse.

Before analyzing these variables and their relationship to our City, let us consider a few of the basic facts surrounding the attractiveness of this particular market.

The City of Syracuse, geographically speaking, cries out for cable television. It includes all the necessary ingredients for a viable and profitable cable system:

- High density
- Excellent strand continuity
- Condensed mileage
- Limited local off-air reception
- Primed subscriber base
- Low percentage underground plant.

Concept

The first conceptual alternatives we shall consider is s Hub-type system. Is there a requirement based on the parameters previously stated.

A. The maximum distance from a centralized distribution point to any extremity of the system will not exceed four miles. NO REQUIREMENT.

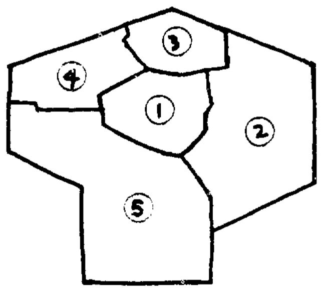
B. Noise-funneling from a total of 300 miles of plant would severely burden bi-directional performance. REQUIREMENT

C. Existing environmental boundaries include only Routes 81 and 690 which are elevated highways for the most part, therefore, they are not obstructing strand continuity. NO REQUIREMENT.

D. POSSIBLE REQUIREMENT.

The limits of bi-directional performance do indicate the necessity for a hub-type configuration. In order to achieve tolerable performance in the reverse direction of a bi-directional cable system, the total nubmer of amplifiers "funneling" from any one sector should be limited to 100 to 130 active devices (amplifiers). A good rule of thumb in estimating the quantity of amplifiers in a system is approximately 2 amplifiers for every mile of plant. This estimate would provide a total of 600 amplifiers (2 x 300 miles) for the City of Syracuse, or the requirement for 5 hubs (600 ÷ 120). The question now remains, where would these hubs be best situated?

Five hubs - five councilmatic districts. Let us investigate how this puzzle might fit. Quite frankly, this concept was a "shot in the dark" initially. The boundaries of the council districts could have very easily been disastrous for this concept. Contrarily, once again, the City of Syracuse opened up its arms to cable television. Another ideal situation for the application of a cable system.



Shown above are the approximated locations of the five districts (a scaled map with precise boundaries has been laid out and is available at the Office of Electronic Communications). Five district areas encompassing an area of approximately 60 strand miles each. How do we then apply a hub-type configuration to these sectors?

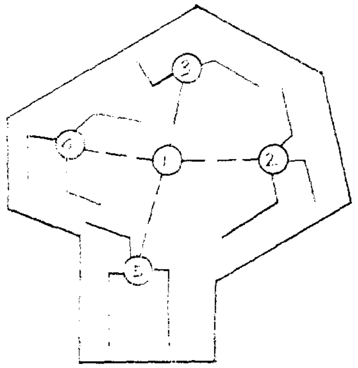
Hub-Type Configuration

In reviewing once again the need for a hub-configuration, it has been established that its necessity is dictated by the requirements of: (1) meeting bi-directional performance; and (2) providing individual trunk feeds to the councilmatic districts. Distance or cascade is not a limitation. Why is this important?

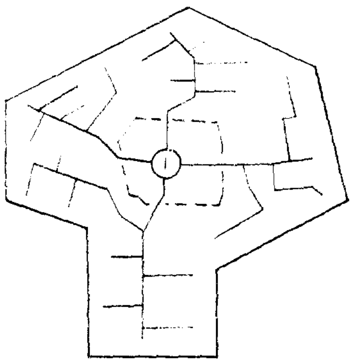
Throughout this evaluation, a "Hub-type configuration" has been stressed in lieu of a "Hub". The end result of this systems concept can be achieved in numerous ways. The end result being a division of the system into five sectors, and those five sectors being the councilmatic districts. A hub is normally a source of distribution remotely located so as to best service a definitive area, independently and interconnected to a master Head-end/Hub via microwave, long haul transportation, etc. This Hub locations can be passive, (a pole location where an amplifier diverts signals to that area's subscribers) or it may be active (located within a building with its own antennae receiver and processing equipment for local origination, etc.). If these sectors were located 10 to 15 miles from the master hub site, this configuration would be appropriate, however, distance or cascade is not a limitation.

This may lead to some confusion, so let's look at this situation graphically.

"Option 1"

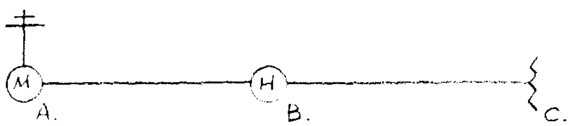


"Option 2"



Option 1 and Option 2 provide identical service. In both examples, (1) indicates the master headend/hub. In Option 1, information is transmitted from (1) to remote hubs via microwave or low frequency RF transmission (bi-directional). This path would carry all signals unavailable locally. At each hub site additional local channels and local origination would be combined with the signals on the interconnect path and then distributed throughout the sector to its subscribers. This is a costly venture, yet a necessity in a system where cascade presents a problem.

As an example, let us compare two cable systems to fully understand the relation of cascade to a system's performance.



	Cable City USA	Syracuse, New York
A-B Distance from master site to centrally located hub:	50,000 (10 mi.)	10,000 (2 mi.)
B-C Distance from hub to extremities of system:	50,000 (10 mi.)	20,000 (4 mi.)
I. A to B @300 Mhz:	20 amplifiers	4 amplifiers
B to C @300 Mhz:	20 amplifiers	8 amplifiers
Total A to C:	40 amplifiers	12 amplifiers
II. A to B @108 Mhz:	11 amplifiers	2 amplifiers
B to C @300 Mhz:	20 amplifiers	8 amplifiers
Total A to C:	31 amplifiers	10 amplifiers
Decrease in cascade utilizing low-frequency interconnect:	9 amplifiers	2 amplifiers

This is an effective demonstration of the relevance of distance to hub utilization. In "Cable City, USA", the extreme distance from Master site to system extremity warranted a low-frequency interconnect, rendering a reduction of nine amplifiers in cascade. This reduction could increase the distribution amplifiers output level sever dB ($70 to $100/mi. savings).

In the case of Syracuse, the reduction only rendered a savings of 2 amplifiers. This would have no impact whatsoever on distribution levels since cascade will not become a determining factor to system levels until it exceeds at least 20 amplifiers. So what does all of this CATV jargon imply? In one simple paragraph it implies:

A Master Hub to Hub interconnect via microwave or low-frequency transportation is absolutely unnecessary. A geographic/demographic division of the City is necessary. This division should be accomplished by providing five multiple trunks from the Master site to each of the councilmatic districts with subscriber distribution commencing once each trunk enters its designated district (see Option 2).

The final alternative to consider is the type of system to be incorporated into this concept of multiple sectors.

There are two obvious choices, and other than these two variations, I would seriously doubt if any other type system would provide all the services and flexibility required for the Syracuse system. These two choices are a Mid-split, dual-trunk with single feeder, and Sub-split, dual-trunk with dual feeder. It is difficult to evaluate which system will be the ideal one for Syracuse, as both are highly sophisticated bi-directional plants. The final decision will more than likely be made in analyzing how the franchise applicant proposes to execute either of these two options.

Seldom does the opportunity arise for the application of a dual plant. Existing dual cable plants throughout the country probably number less than 2%. Why such a low percentage? A dual cable plant is unequivocally a financial disaster without the proper DENSITY and CONTINUITY.

Initial cost of dual versus single plant can be evaluated by applying the following formula:

Where: D_s = Cost per mile of single plant distributions.
D_d = Cost per mile of dual plant distribution.
x = Difference in cost per mile of single vs. dual.
S_s = Cost of subscriber installation in single plant.
S_d = Cost of subscriber installation in dual plant.
y = Difference in cost of subscriber installation.
n = Number of subscribers per mile.

IF: X > (yn) = Single Plant
X < (yn) = Dual Plant

Formula:

$D_d - D_s = x$

$S_s - S_s = y$

* > = Greater than
< = Less than

Assume:

$D_s = \$5,500$

$D_d = \$8,000$

$S_s = \$55$

$S_d = \$30$

n = 50 subscriber miles

Applied:

$D_d - D_s = x$ or \$8,000 - \$5,000 - \$2,500

$S_s - S_d = y$ or \$55 - \$30 = \$25

x = \$2,500
y = \$25
n = 50
yn = \$1,250

IF: x = > (yn) = Single plant
x = \$2,500
yn = \$1,250

THEN: \$2,500 > \$1,250 = Single plant

IF: n = 100; yn = \$2,500; = Single or dual plant

n = 150; yn = \$3,750; = Dual plant

In analyzing the point of crossover for single versus dual plant it becomes apparent in applying the formula that the value of "x" is most critical. Its importance becomes even more critical as the value of "n" decreases.

The value of "x" and "n" will fluctuate in different cable plants. "X" relative to continuity and "n" relative to density. "Y" will remain constant in any system. The cost of subscriber materials is in no way effected by system parameters. The value of "y" is derived as shown below.

Subscriber Material	Single Plant	Dual Plant
Cable(\$3,500/100')	3.50	7.00
Gro Block (.40/ea.)	.40	.80
Transformer (.45/ea.)	.45	.45
"F" connectors (.08/ea.)	.56	.88
Labor	12.50	18.50
Converter	40.00	--
A-B Switch	--	4.50
Total	\$57.41	\$32.13

Y = \$25.28

The better the strand continuity, the smaller the value of "x" will be. The higher the density, the higher the value of "n" will be. What then is the approximate application for Syracuse?

Syracuse- 223 homes passed/mi. @ .45% Penetration - 100 subscriber/mi.

IF: y = \$25 (known)
n = \$100 (known)
yn = \$2,500

IF: x > \$2,500/mi. = Single Plant
x < \$2,500/mi. = Dual Plant

at 50% penetration yn = \$2,800
at 60% penetration yn = \$3,350
at 70% penetration yn = \$3,900

The value of "x" will always be greater than \$2,000 in any system, regardless of how the system appears geographically. Recognizing this, along with the constant value of "y" at approximately \$25, if "n" is ever less than 80 subscribers per mile a dual plant is generally unaccpetable. Remember that "n" is subscriber/mile and not homes passed/mile. Assuming a penetration of 50% a cable system requires the equivalent of 160 homes passed/mile in order to justify a dual cable plant. Hence, less than 2% dual plants nationwide.

Recognizing the definite possibility of a dual plant system for Syracuse because of its

Marketability

Advantage	Disadvantage
- Two tier basic service	- Eliminates remote control
- Two tier pay service	- Additional wiring required
- Rate versatility	- For multiple units (pre-wired).

Flexibility

Advantage	Disadvantage
- 8 return video channels accessible at any location in city.	- 18 channel max forward.
- 40 return channels total	- Multiple drops pottential.
- Private access via converters	- Environmental eyesore
- Lower maintenance costs.	

Here we encounter the barriers which counterbalance the previously mentioned economic advantages of a dual plant. This is not to say they totally eliminate the execution of this concept, but their importance must be evaluated. This evaluation is quite simple. The questions to be answered are:

1. As a consumer, and being presented with a choice, would you prefer the convenience of a remote control device (converter) rather than an A-B type switch controlling the TV set channel selector?

2. As an apartment building owner, would you object to having to pay the additional costs of wiring your complex for dual system having already expended the money for your existing MATV system?

3. Does the Syracuse market require more than 18 cable channels?

4. Will the ecology mindful citizens of the community object to the excessive required for a dual plant?

If your response to any of these questions was "yes", your evaluation has rendered a veto against a dual plant concept.

Our final consideration then is a single plant concept, actually a modified single plant, incorporating a second parallel trunk for bi-directional capabilities.

This system is capable of delivering:

- 35 channels in the forward direction of the "A" turnk.
- 4 channels in the return direction of the "A" feeders.
- 20 channels in the forward direction of the "B" trunk.
- 12 channels in the return direction of the "B" trunk.

Obviously, there are no limiting factors here in relation to channel capacity. These 35 channels would be delivered to the TV set by a set/top or remote control converter. This type system would also fit into the previously determined hub-type concept.

This configuration would also enable the activation of the alarm system from any subscribers dwelling within the city. Municipal access may be incorporated via the return feeders of cable "A" or via the return trunk of cable "B".

Marketing of this system might also be a two-tier concept. Tier #1 offering up to 9 channels without converters at oneprice and Tier #2 offering up to 35 channels utilizing the converter at an optional price.

ISBN 0-940272-01-6; 0-940272-08-3; 0-940272-10-5; 0-940272-11-3; 0-940272-12-1; 0-940272-14-8; 0-940272-15-6; 0-940272-16-4; 0-940272-18-0; 0-940272-19-9; 0-940272-20-2; 0-940272-21-0; 0-940272-22-9; 0-940272-23-7; 0-940272-24-5; 0-940272-25-3; 0-940272-26-1; 0-940272-27-X; 0-940272-28-8; 0-940272-29-6; 0-940272-32-6; 0-940272-33-4; 0-940272-34-2; 0-940272-35-0; 0-940272-36-9; 0-940272-37-7; 0-940272-38-5; 0-940272-39-3; 0-940272-40-7; 0-940272-41-5; 0-940272-42-3; 0-940272-43-1; 0-940272-44-X; 0-940272-45-8; 0-940272-46-6; 0-940272-47-4; 0-940272-48-2; 0-940272-49-0; 0-940272-50-4; 0-940272-51-2; 0-940272-52-0; 0-940272-53-9; 0-940272-54-7