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ABSTRACT

A 12 CHANNEL, 8.6 KILOMETER FIBER OPTIC SUPER TRUNK

Installation of the titled Super Trunk, for Teleprompter of Lompoc, CA was completed on December 7, 1978 and announced during the meeting of the California Cable Television Association in Anaheim, CA.

The installation process was begun on November 17, with the mounting of Repeater Housings on selected poles and energization of Repeaters and Terminal Equipment. This was followed by the installation of cable containing 3 optical fibers and subsequent splicing/connecting procedures.

Fully described is the Optical System, it's measured performance, the installation experience and the systems reliabvility and maintenance history.

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Complete text is either printed in appendix B or available upon request from the author.

A CHARM SCHOOL FOR INSTALLERS AND TECHS?

WHO NEEDS IT!

A Presentation To The National Cable Television Association
By Sheldon B. Satin, Sheldon Satin Associates, Inc.

A. Three reasons why your people don't need customer relations training.

The first step in the development and implementation of any training program is the establishment of a need for it.

The following are some of the objections that have been raised by those who are unfamiliar with the objectives and content of a customer relations program for installers and service technicians.

1. It's not our job!

"Our job is making sure an installation is done correctly and that our customers continue to have good reception."

"Let the salesmen and the people in the office worry about PR."

In a service-oriented business what the customer thinks about the people is just as important as the quality of the service.

It's critical that every contact with the customer is a positive one.

Installers and technicians are in the front line when it comes to influencing a customer's attitude about the system. In many communities they are the customer's only personal contact with the system.

2. There's no time!

"Customer relations is important, but we don't have enough time to adequately train our people to perform the technical part of their job."

Customer relations training doesn't require many hours of training if the program is well organized and structured properly.

3. We do it already!

"We believe that good customer relations is important, but there's no reason to set up a formal training program."

"We always tell the men to be pleasant to customers and not to let the few bad apples out there get to them."

Telling installers and service techs to be nice doesn't give them any information on how to be nice. Telling them not to let angry, difficult or dissatisfied customers bother them doesn't tell them what to do to diffuse these customers so that the reason for the problem can be found and resolved.

B. What are the objectives of a customer relations program?

The overall objective of the program is to create a better climate between your system and your customers.

This happens when training focuses on the following three areas:

1. "Sensitize" installers and technicians to the human relations part of service to customers.

2. Equip them with a clear explanation of company policies so they know what they can and can't do in dealing with customers.

3. Give them specific responses to customers' questions and complaints.

This will make the non-technical requirements of their job clearer to them so they in turn can be clear and helpful to customers.

With the proper program, installers and service techs will be able to spot problems and pass the information on to the right place for action.

Corrective activity in the early stages of customer dissatisfaction will minimize customer resentment which could result in either:

. a refusal to order additional service
. eventual disconnection

C. <u>What are some of the topics in a customer relations program?</u>

Each system is different, but in general, these are the topics which most installers and techs talked about during their interviews:

- Professional attitude and image
- Doing the job right
- Listening to the customer
- Attitudes about customers
- Attitudes about the company
- Initial customer contacts
- Company policies
- Possible customer conflicts and how to avoid them
- Collecting money
- Retrieving company equipment
- Teaching customers to self-adjust controls
- Responding positively to customers' questions about your cable TV services

D. <u>How should a customer relations program be developed and implemented?</u>

These are the main steps in setting up the program:

1. Interview the installers and technicians to identify the types of customer and company-related situations they encounter.

2. Review all customer-related policies and procedures relating to installation appointments and service calls.

3. Prepare a training manual.

   We recommend organizing the information into 5 sessions with questions and answers at the end of each session.

4. Prepare a discussion leaders guide.

5. Select and train a discussion leader to conduct the workshop sessions.

6. Organize the workshop sessions.

   The workshops last from 1½ to 2 hours. Reading the materials and answering the questions should last no longer than 45 minutes.

The remaining time is spent discussing the questions asked by the discussion leader and in role-playing.

Limit each workshop to 10 participants and schedule them at the beginning of the day so that appointments can be scheduled immediately following each session.

7. Provide support materials such as policy cards, questionnaires, etc. and a certificate of award for every participant who completes the program.

8. Provide incentives to reward their continued use of the techniques they've learned.

Customer relations training is not a charm school. It is a means of providing your installers and technicians with the tools they need in their daily contact with customers.

Providing these tools will yield many positive results:

Your people will be happier in their jobs because they will view the program as a sign that management cares about them; you'll have fewer customer related problems and complaints; and your productivity and efficiency levels will increase. It will be a better place to work for your staff, and greater profits for your system.

ABOUT SHELDON SATIN

Sheldon Satin is president of Sheldon Satin Associates, Inc., a New York-based management consulting firm specializing in the area of industrial communications.

In 1970 he founded Trockmorton/Satin Associates, Inc., a direct response advertising agency with clients in the fields of banking and publishing and various consumer products.

He was executive vice president of the Electrographic Corporation following their acquisition of VPI, one of the largest companies engaged in the operation of film and videotape production facilities, editorial and optical houses, film laboratories and print distribution companies. Mr. Satin was president of VPI.

He is a graduate of Oberlin College and Indiana University.

ABOUT SHELDON SATIN ASSOCIATES, INC.

Sheldon Satin Associates, Inc. is a management consulting firm engaged in a wide variety of activities for various industries.

The firm has produced all of the national affiliate training programs for Home Box Office and the first Satellite Seminar for Teleprompter.

Satin Associates has adapted the American Airlines' TACT program for the cable TV industry. TACT workshops train customer contact personnel to understand and to deal effectively with dissatisfied customers.

Leading independent and multiple systems operators in the cable industry are clients of Satin Associates. Among them are American Television and Communications, Communications Properties, Inc., Cox Communications, Canadian Cablesystems, Cablevision Systems on Long Island, Gill Cable, Rogers Cable in Toronto, Tele-Communications, Inc., Teleprompter, Times-Mirror, United Cable, Viacom Communications and Warner Qube.

Other clients include the Mobil Corporation, The Lincoln Center for the Performing Arts, Modern Talking Pictures, The Television Corporation of Japan and Wells National Services, a division of American Hospital Supply.

A VERSATILE, LOW COST SYSTEM FOR IMPLEMENTING CATV AUXILIARY SERVICES

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ABSTRACT

A versatile, low cost system for implementing CATV auxiliary services is presented which focuses upon a basic unit operating over two-way coaxial networks. A wide variety of services can be implemented with the basic hardware. In addition, this unit can be extended to implement more complex functions in a modular manner requiring the cost increase only at the specific locations where the more complicated task is undertaken. This type of system lends itself to many areas such as security, energy management, traffic control, industrial data gathering and process control, CATV system status monitoring and spectrum analysis, hotel security and room services, low and medium speed data communications, addressable taps, premium CATV control, remote switching of all kinds and a host of others.

INTRODUCTION

The past several years have brought many new non-entertainment services into the field of CATV and RF coaxial communications. The concept of the wired nation is slowly and systematically developing based upon those auxiliary services carried on the cable which in themselves offer economic viability.

There has been a great deal of progress in data communications on coaxial systems. In various cities and certain industrial plants hundreds of point to point data circuits are in operation linking computer to computer, computer to peripherals, etc. These services usually involve continuous high volume transmissions of data and operate at data rates from 100 to over 1 million bits per second. These services are implemented over coaxial links which typically involve CATV transmission components. Modems capable of synchronous or asynchronous operation have been developed. These modems provide fair to good spectral efficiencies and can be characterized by excellent performance and moderate to high unit prices.

As these high volume services have expanded there remains a need for systems and hardware to do the "simple tasks" which do not, in themselves, warrant the assignment of costly hardware. These "simple tasks" are typically: servicing security systems where one need only know the status of a security zone which changes occasionally; the necessity to command a remote function such as opening a door, turning on a light, switching on an air conditioner, etc. These "simple tasks" exist in security, system control, CATV premium services, energy management, hotel management, industrial process control, and a host of others.

We have, in the past few years, seen the development of specialized CATV hardware to implement some of these "simple tasks", i.e., security, traffic light control, and audio intercoms. Little, however, has been done in terms of universal hardware which can be applied in a transparent fashion over a wide spectrum of services.

This paper describes the TRU Coaxial Communications System. This equipment has been designed as a universal, digital, receive and transmit modem, operating within the traditional CATV spectrum. The TRU System can be applied to the full spectrum of "simple tasks" and is readily expandable to more complex functions requiring intelligent terminal behavior.

TRU SYSTEM

The TRU System is designed to operate on a two-way coaxial network. Operation in the receive-only mode in one-way systems is possible at the expense of certain of the system features. The TRU System is organized with a central controller and any number of remote units (TRU-100) up to the addressing capacity of the system (over four thousand). It is a polled system in that the control unit addresses each remote in a predetermined sequence, passing data to the remote and eliciting a response. The remote terminal's response to the poll indicates its presence and can be accompanied by data to the central controller. Figure 1 is a photograph of the TRU-100 remote unit.

Figure 1 - TRU-100 REMOTE UNIT

The TRU System utilizes radio frequency transmission on the coax and therefore every TRU-100 unit contains an RF receiver and transmitter. Both transmitter and receiver sections are crystal controlled and utilize frequency shift modulation. The occupied bandwidth is 250 kHz in each direction (upstream and downstream). Both transmitter and receiver are simple in design but effective in operation and highly reliable. Figure 2 is a block diagram of the TRU-100.

The data portion of the TRU-100 is organized around a low power microprocessor which handles the addressing and data handling and is available for expanded tasks which will be discussed later. The TRU-100 has a number of powering options. Since, in many applications, it is not desirable to have AC line voltages within the unit the TRU-100 is designed to operate on low voltage, external AC or DC (12 volts), or 30 or 60 volts cable power. In addition, a battery back-up option is available, allowing approximately 2 hours of operation on rechargeable Nicad batteries. These batteries are under constant trickle charge when the unit is normally powered.

The TRU System operates on a polled basis under control of the user's computer or a stand-alone, microprocessor-based, TRU controller. The master modem is simply a TRU-100 remote unit with the transmit and receive frequencies interchanged or translated so that the master transmitter will be on the same frequency as the remote receivers and vice versa. This variation is called the TRU-200. In operation all remote units listen continually on the same frequency. Each unit receives all messages and searches for its unique address. Figure 3 depicts a typical TRU System.

The data transmission both to and from the remote units utilize the same speed and general format. The data rate is 38,400 bits per second (38.4 kBs) in a standard 11 bit asynchronous character format. The 11 bits include a START bit, 8 data bits, a parity bit, and a STOP bit. Each transmission includes a initialization byte (a byte is one 11 bit asynchronous character), a control byte, one or two address bytes, and optional message bytes. The system is capable of addressing over 4,000 units using 12 binary bits which require 2 address bytes. A system of 250 units or less needs only 8 bits for addressing and therefore utilizes only one address byte.

The control byte has numerous housekeeping functions including specifying the number of data bytes in a given transmission. In some cases it is only desirable to know that a remote unit is there and functioning. In this case data messages, downstream or upstream, are not necessary and no data bytes are transmitted in either direction. In the more common application, a number of message bits are transmitted downstream along with each poll and a specific number of status bits are returned with each remote unit response.

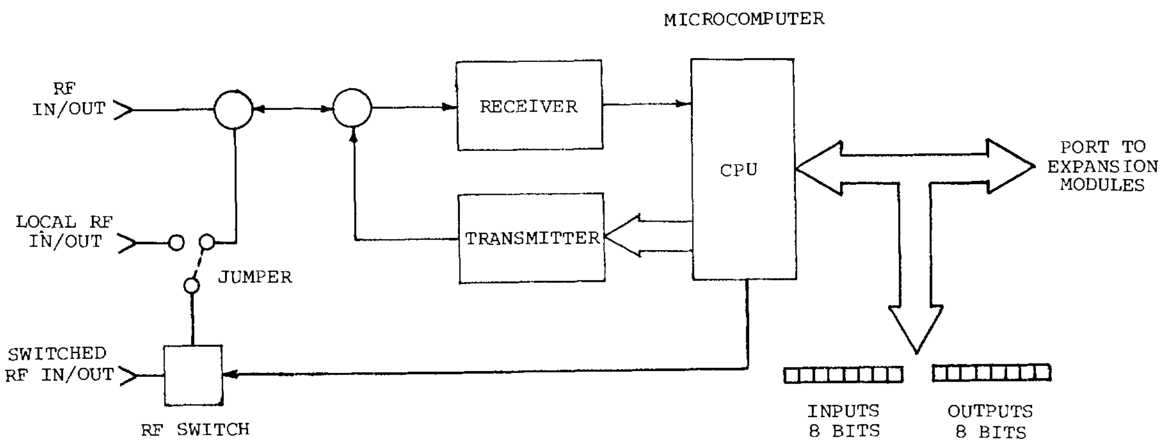

Figure 2 - TRU-100 BLOCK DIAGRAM

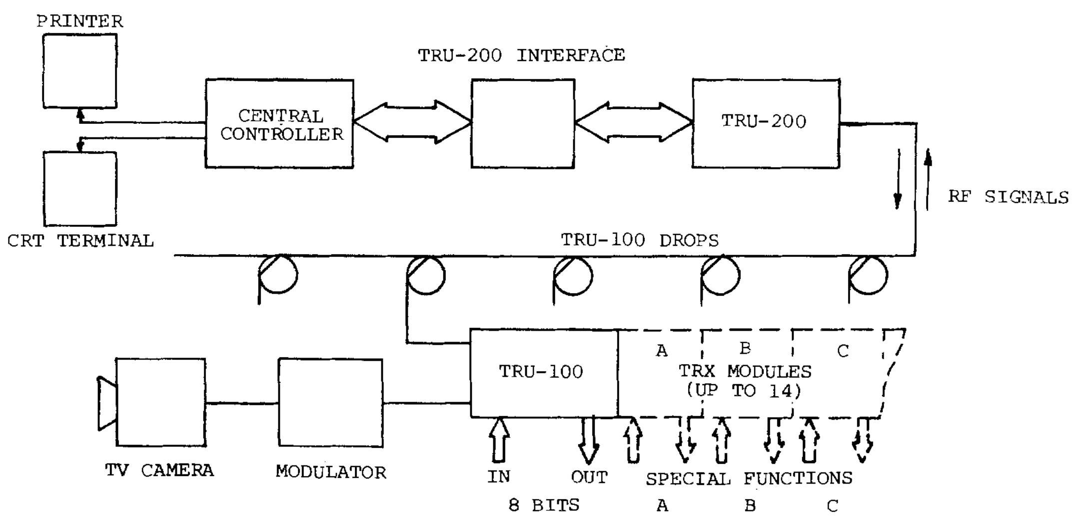

Figure 3 - TYPICAL TRU SYSTEM

The TRU-100 remote unit is organized to receive 8 bits of data on each downstream poll. These are presented as 8 saturated transistor outputs, with high voltage protection, on a terminal strip within each unit. The TRU-100 receives one additional bit of information on each poll which is utilized to open or close an RF switch that is contained within the unit. This RF switch can be arranged to switch the entire cable system downstream spectrum, as would be required to turn a CATV drop on or off. It may also be configured to switch a local RF source, such as a modulator for a camera, thereby allowing central command of local RF functions.

Every time a TRU-100 remote receives a poll it immediately responds. The normal response can include the entire address or a portion of the same at the system operator's discretion. This response verifies that the unit in question is active and has received a valid address and has responded to it. The TRU-100 at this time can return 8 bits of status information. These 8 bits are presented to the TRU-100 as either switch closures or logic level signals at 8 additional points on the terminal strip.

It can be seen that both the downstream and upstream information can readily be applied to all sorts of services. Security zones can be sensed as well as thermostat closures, panic button actuations, and status indications of all kinds. The downstream information can also be used in many ways. Blowers, compressors, air conditioners, etc. can be controlled for energy management; door strikes can be actuated for security; camera controls can be implemented; and various functions can be activated in process control systems; to mention but a few.

In summary, the basic TRU-100 can be employed in systems as large as several thousand units. The entire system occupies only one 250 kHz channel in the upstream direction and one in the downstream direction. Eight bits of data can be supplied on every poll plus control of a local RF switch, and 8 bits can be returned on every response. Polling of all units in a system of 250 can be achieved several times every second. All units in a system of 4,000 units can be accessed once in approximately 6 seconds. It can be seen that the basic TRU System can be widely applied and provide a low cost means of implementing many, many status and control functions where communications on a coaxial system are available.

EXPANSION

There is a large additional area which has been addressed in the TRU. In many systems, requirements arise which will not fit conveniently within the basic "8 bits down, 8 bits back" format. As an example consider complete control of a surveillance camera. In this case pan, tilt, zoom, and iris control need to be implemented with two functions each (up/down, left/right, etc.) plus high and low speed. There are often other camera controls such as power, windshield washer and wiper, heater, cooler, etc. It is also desirable, in certain applications, to have preset options available and to provide common sync for the cameras. It is obvious that there are many more functions here than can be handled with the 8 control bits available on the basic TRU-100.

The design of the TRU-100 is such that the microprocessor system buss and control lines are available for this eventuality, on a printed circuit connector conveniently located at one end of the unit. When a particularly complex task is required, a TRU extender (TRX) is constructed which includes the hardware necessary to do the task. In the case of elaborate camera controls, this hardware includes some electronic circuitry and a number of relays to switch the relatively high voltages and currents needed by the various camera and mount functions. This module interfaces with the TRU-100 processor buss and also contains the program to direct the special functions provided by the module. In this case, the downstream data required to control the camera might well employ three or four 8 bit data words on each downstream poll. As mentioned before, the basic system protocol is capable of expansion to the required number of data bytes necessary for each individual remote unit (the 8 bits down and back are still available for other uses such as security zones, door strikes, energy management, etc.). The TRU-100 remote unit is capable of accepting up to 14 modules which may be individually or collectively addressed.

The advantages of the TRU System organization described above are numerous.

1) The basic system is low cost, which allows deployment for simple tasks while retaining economic viability. When more complex tasks are implemented with plug-in modules, these modules need only be installed at those locations where the particular functions are required. In

this way the economics of function expansion are excellent as there is no need for the whole system to be upgraded.

2) All TRU-100 remote units (excluding plug-ins) in a system are identical with the exception of the specific addresses which are set in at the time of installation. This means that logistically there is no difference between remote units. One spare TRU-100 carried by a service man can be used to replace any unit in the field.

3) The loading of the data stream by the more complex tasks with greater transmission requirements again is not system wide, but only to the extent necessary to service the specific extra capability modules, and only at those specific times when extra data is necessary.

4) Additional units can be added to the system at will. It is simply a matter of installing a proper cable drop and adding the additional address to the polling index and setting it into the TRU-100 remote.

5) The system is self-testing since the system controller is immediately alerted to the fact that there is trouble when either no answer or an improper answer is received to a poll. In this manner diagnostics of system problems such as broken cables, amplifier outages, and the like can be done from the central control point and lead to rapid identification, location, and correction.

TYPICAL APPLICATIONS

The following are brief descriptions of typical applications and installations of the TRU System. These are not complete in every detail but do serve to illustrate the various applications and implementations using the TRU equipment.

Residential Security Carried on Entertainment CATV Network

This is a typical situation in which a CATV operator wishes to develop a source of additional revenue. Generally a security service is contracted to respond to alarms, while the CATV operator is responsible for the transmission equipment and system maintenance.

Let us assume that it is desired to provide intrusion security, smoke detection, medical alarm, panic alarm, and power outage sensing. Let us also assume a requirement to control residential outside lights and siren or bell alarms from the central station. All of these services are to be offered to the customers on the system, but can be individually accepted or rejected. Regardless of the number of services selected, each customer is supplied with a TRU-100 remote terminal. This is mounted in an inconspicuous space within the residence. Each TRU-100 can handle up to 8 separate commands downstream and return 8 separate bits of status information upstream. In the case of intrusion protection, the residence is wired with normal sensors, such as window and door switches, tapes, sonic, infrared, or microwave motion detectors, and the like. If simple loops are employed, no security junction box is needed, reducing the cost of the sensor installation. All circuits terminate at the TRU-100. It may be desirable (or more convenient) to assign separate bit inputs on the TRU-100 to separate zones of the residence, or separate sensors, such as motion detectors. Any arbitrary assignment is acceptable as long as correlating information is given to the controlling computer at the central station. Medical and panic alarms are handled in the same manner by utilizing separate bit inputs on the TRU-100. Power outage sensing is automatically provided through control information in the TRU data stream (in addition to the 8 bits under discussion). If local power goes off, the TRU-100 will continue to function for approximately 2 hours on its internal batteries, however, an alarm will immediately be given and service personnel can be dispatched.

Since downstream control is possible there are many deterrent measures which can be instituted by the central station operator. It may be desirable to delay lights and alarms after violation of a security zone and put them under the control of the central station operator. Interfacing to these services from the TRU-100 can be handled directly if low voltage DC control circuits are available. In the case where higher power must be controlled, an external relay is required whose control winding is connected to a power supply and to the TRU-100 (power relays are available in modules such as the TRX-403). Figure 4 gives a schematic representation of a typical residential installation.

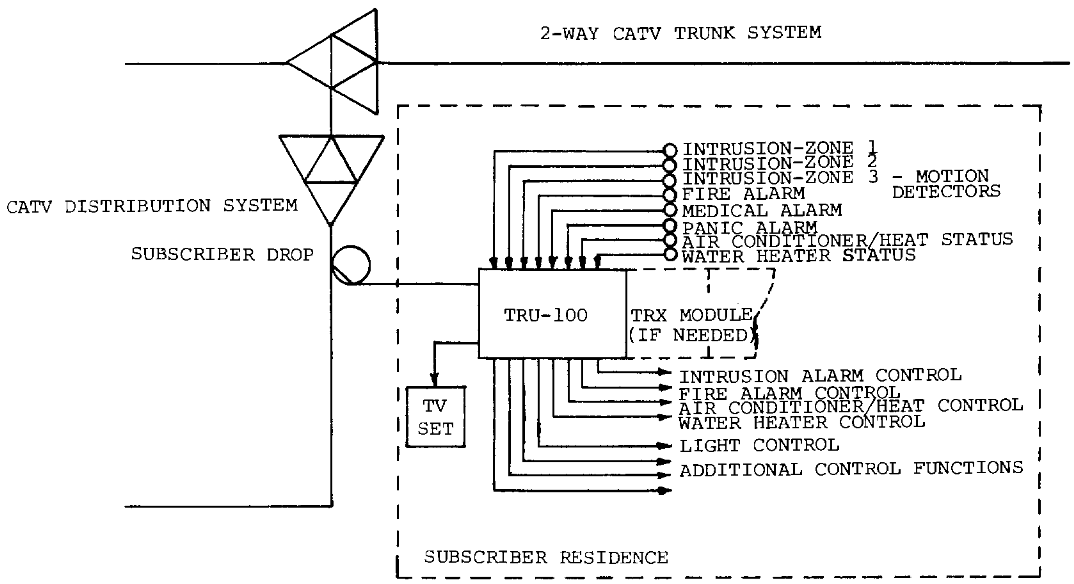

Figure 4 - TYPICAL TRU/CATV RESIDENTIAL APPLICATION

The TRU system employs a master modem (TRU-200) which is connected to an intelligent controller, programmed for the functions required. The control system is often available at the local security central station so that only a TRU interface module is required to connect the TRU-200 to the security controller. In stand-alone systems a series of special TRU controllers are available.

In any of these systems the controller (or special interface unit) initiates the polling of the remotes. The controller stores the normal status of each control bit and alarms changes and reads out pertinent information of the location, owner's name, response instructions, and the like.

It can be seen that even with a rather elaborate security installation the TRU-100 (8 bits down, 8 bits back) provides enough information for complete monitoring and control with some capability left over. In addition, the RF switch in the TRU-100 allows the cable operator to control the TV service either in a connect/disconnect fashion or, by switching of traps or descramblers, for pay TV or similar services. Any unused data is available for other services. In many areas the local power companies are doing residential load shedding in high demand periods by shutting off air conditioners, water heaters, etc. for short periods of time, as required for load reduction. Transmission of the monitoring and control functions for such services can be provided by the CATV operator through the TRU-100 and interfaced with the electrical devices through power company supplied relays or control devices.

Commercial Building - Security and Energy Management

Numerous systems exist for security and energy management in commercial buildings. They are generally based upon installation of twisted pair cables from the central location in the building to each area where control is desired. A prime advantage of using the TRU System is greatly reduced wiring cost since the entire building can be served on a single coaxial cable using CATV drop techniques. The cost of installation is considerably less than the equivalent twisted pair installation. In small and medium size buildings repeater amplifiers are unnecessary. In larger buildings, indoor distribution amplifiers with two-way options may be required. Wherever control is necessary, a standard directional tap is installed to provide the drop with proper signal levels.

One TRU-100 remote unit can service a total of 8 signals coming from security or energy management sensors. With this capacity several rooms may be served with one TRU-100. The security zones and energy management sensors (thermal switches, etc.) are connected to their appropriate bit inputs on the TRU-100. Energy management controls (usually relays) controlling fans, air conditioners, heaters, etc. are connected to the downstream terminal strip on the TRU-100. The control bits in most cases are programmed as latching functions but momentary operation with selectable duration is also available. Latched functions allow a device to be turned "on" and not serviced again until it is required to be turned "off". Since polling is quite rapid in comparison to the length of the device control cycle, the main controller can be programmed to repeat the command at intervals, as a confirmation of the command. This is easily accomplished in the normal polling routine of the controller.

A system in a commercial building is similar to the residential system although it might be considered to be a private CATV network. There is no need to connect to "the outside world" since all of the functions and control decisions are made within the building or building complex. The same TRU System can be extended to entrance and roof door security, smoke and fire sensors, and a multitude of other tasks.

When this system is installed it is obvious that the wide bandwidth of the coax is available to handle other services. Many security cameras can be distributed throughout the building and returned on separate RF channels to the monitoring location. In a case where the amount of spectrum available for surveillance cameras is limited, it might be desirable to assign several cameras to one RF channel. In this case the TRU-100 RF switch feature can be used to gate only one camera at a time. This reduces the number of video channels required on the cable system and eliminates the need for a sequential switcher at the monitor point. TV can also be distributed and sold to occupants of office suites. Audio channels can be carried and, as a matter of fact, the TRU System can be used as an intercom controller. Figure 5 illustrates a commercial building TRU System.

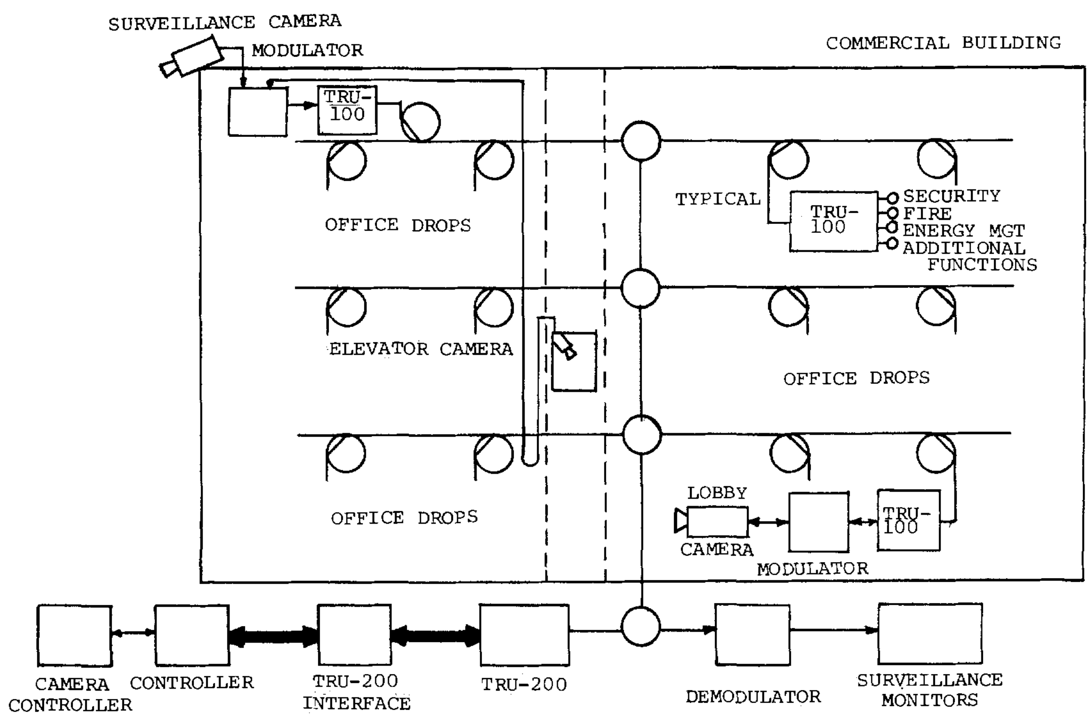

Figure 5 - TYPICAL TRU COMMERCIAL APPLICATION

Industrial Monitoring and Control System

More and more industrial users are employing coaxial communications networks. These have been dubbed "broadband systems" and are now the subject of possible standardization by the EIA. The advantages of broadband are: lower cost of wiring, immunity to noise, resistance to severe environments, and extremely large information capacities, all of which are most attractive to industrial users.

Many industrial processes utilize computer control. In present systems there are a number of limitations imposed by utilization of twisted pairs to interconnect sensors and processing equipment. In many cases minicomputers must be placed in undesirable plant environments to reduce the twisted pair cabling connecting to the sensors. Employment of the TRU System allows location of the TRU-100 remote units in the sensor areas but removal of the processing computers to office environments.

There are other advantages of employing the TRU System. In many cases ON/OFF monitoring is all that is required along with ON/OFF commands. In these instances the basic TRU-100 can supply 8 separate downstream commands and receive 8 separate upstream status signals, all of which can be serviced on each poll. In many applications, however, there are more complex requirements. There is often a need to transmit analog information. This is accomplished in the TRU System by addition of TRX modules with A/D and/or D/A converters which allows digital carriage and processing of the analog signals. Several versions of these modules give a choice to the system designer. A/D conversion is available in 8, 12, or 16 bit resolutions. Commutation switches with 4, 8 or 16 ports are also available to allow the collection or dissemination of data from more than one sensor or transducer at a given TRU remote location. Note that only those locations in a system requiring the special functions need to be outfitted. This means that the cost of the system is only increased at those locations where increased capability is required.

There are still other extensions of the TRU-100 for industrial applications. Since the data processing in the TRU-100 is accomplished by a microprocessor, this computing power is available to any auxiliary function. In a special application it might be required that data be taken locally at a relatively high rate, reduced or processed to obtain peak values, averages, minimums, etc. and the result of these computations, transmitted to the central point when the unit is polled. In a case like this the firmware necessary to implement the data processing is supplied in the special TRX module. In these cases the TRU-100 has become a very intelligent data gathering and processing terminal. The TRX-501 module allows interfacing of low and medium speed asynchronous terminals to the system. By use of the TRX-501,any terminal in the system can communicate with another on an apparent point-to-point basis. The scope of applications for these techniques is limited only by the system designer's imagination.

Other Applications

It can be seen by the three specific applications above that the TRU-100 system can be applied throughout a large area of command and/or monitoring applications. Hospital systems can employ the TRU for nurse call, intercom, data transmission, control and monitoring of medical electronic devices, security, energy management and many other things. Traffic and traffic light control is another obvious application of the TRU System.

Status monitoring and control in CATV systems is also quite attractive. Simple cable amplifier operating functions such as power and AGC monitoring can be done with the standard TRU, leaving additional inputs and outputs for feeder and tap switching, etc. More complicated functions such as remote summation sweeping or spectrum analysis can be accomplished with plug-in TRX units. Microwave system monitoring and control can also be implemented. The list goes on and on.

In summary, the TRU System is an extremely versatile command and monitoring system capable of expansion to more complicated functions, making use of the ubiquitous coaxial communications network.

A WIDEBAND DATA TRANSMISSION LINK UTILIZING EXISTING CATV AND MICROWAVE FACILITIES

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ABSTRACT

An experimental wideband data communications network has been installed at IBM's Systems Communications Division facility at Research Triangle Park (RTP), N.C. The network connects display terminals and other devices with a central computing facility. The network is a dual cable, full duplex, 5-30 MHz and 50-300 MHz system.

Connection of terminals to two other IBM locations in Raleigh, N.C., about 22 land miles from RTP, is also provided. These signals are transmitted from RTP to American Television and Communications' (ATC) microwave tower in Durham, via ATC's Durham cable system.

Then the signals are carried by a one-hop ATC common carrier microwave system to ATC's Raleigh tower. And then, via ATC's Raleigh cable system, the signals are carried to the IBM Raleigh facilities.

INTRODUCTION

In late 1976, IBM approached ATC about a data transmission requirement between IBM facilities at RTP and their facilities at Raleigh.

Because of the nature of the modulation used, a requirement for the communications service was the IBM signals could not be demodulated and remodulated. Instead, the nature of the signals suggested the spectrum occupied by them should simply be translated up and down in frequency, as might be required at any of the interface points between segments of the proposed network. This requirement would obviously be easier to accomplish if the number of interface points were kept to a minimum.

The experimental in-plant cable system and the microwave link described here were installed as part of an IBM Advanced Communications Technology program at RTP. The primary purpose of the installation was to gain experience in the transmission of data over CATV and microwave networks.

Another major objective was to uncover related practical problems, such as specifying the electrical parameters of such networks, procuring vendor services for system design, and coordinating vendor installation of CATV cable in laboratory, office and manufacturing environments.

Also, network performance measuring techniques had to be devised and routine preventive maintenance procedures established. The application chosen to be implemented on the cable system was the connection of display terminals to a central computing facility. At present, about 500 such terminals are distributed throughout the approximate two million square feet of building space at the IBM RTP complex.

At this time, ATC was already operating a CATV system in Raleigh, and ATC's Microwave Mid-Atlantic System was operating common carrier facilities between Durham and Raleigh, and was preparing to start construction of the Durham CATV system.

Several methods of establishing the proposed network were discussed. The one finally chosen used the CATV systems at both ends of a one-hop microwave system (Fig. 1). This, however, required interfaces to be designed for both ends of each CATV segment of the system.

The result was four separate interfaces. This alternative added two additional interface points compared, for instance, to an all-microwave approach. But the consensus was that this was a fair trade-off for the experience we hoped to gain.

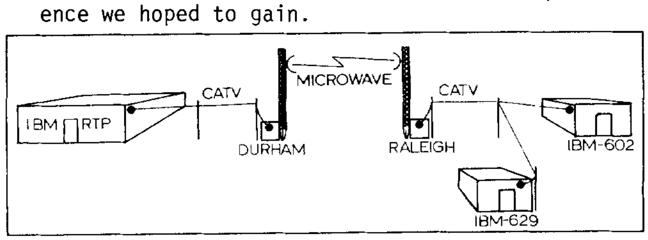


FIG. 1 RTP TO RALEIGH DATA NETWORK

There were several more discussions with IBM about end-to-end signal transmissions requirements. Then Farinon Video and the CATEL division of United Scientific Corp. were contacted about hardware requirements. Both vendors wanted to participate in the project. Subsequent technical meetings were held among the participants, to determine interface parameters, system operating levels, and other system requirements.

For instance, IBM requested that two high-rate 1.2 M b/s data signals 3 MHz apart should be centered in a 6 MHz channel and should be carried at equal amplitudes throughout the network. This meant the signals would have to interface with the microwave radios at baseband rather than at 70 MHz IF. The nature of FM signal processing dictated this.

If an attempt was made to interface two equal amplitude carriers at IF, the FM limiting action in the IF amplifier would cause intolerable IM products to occur. However, with a baseband interface, both signals would be accepted as baseband modulation. However, the total power loading on the radio should be no greater than would be the case with 1 volt peak-to-peak of video measured at 75 ohms.

Then IBM requested two more signals be carried through the network. The first was a 230.4 K b/s full-duplex data-service signal. The second was a tone-activated loop-back test system, to aid in fault location throughout the network. It was decided to carry these additional signals as subcarriers. Therefore the equivalent power loadings on the radios were re-adjusted accordingly.

Close cooperation by everyone resulted in prototype interface hardware being quickly developed. The initial bench testing of the IBM modems through the CATEL interface equipment provided satisfactory results. And thus the final system hardware was fabricated.

The field installations of the cable segments and associated interface equipment were done in parallel with the installation of the Farinon microwave radio equipment. The only change required in the Farinon equipment was to replace the 5 MHz baseband filter with an 8 MHz baseband filter. The standard video pre-emphasis and de-emphasis networks were used to maintain an acceptable Signal-to-Noise Ratio (SNR) end-to-end.

DATA NETWORK AND INTERFACES EXPLAINED

To better visualize the end-to-end wideband service provided by the network, please refer to Fig. 2. Starting at the RTP end, the IBM data carriers are injected directly into the end of the cable at 16.5 MHz and 19.5 MHz at the proper level.

The 230.4 K b/s data is impressed on the cable by the transmitter portion of the 230.4 K b/s modem at a frequency of 7.1 MHz. Additionally,

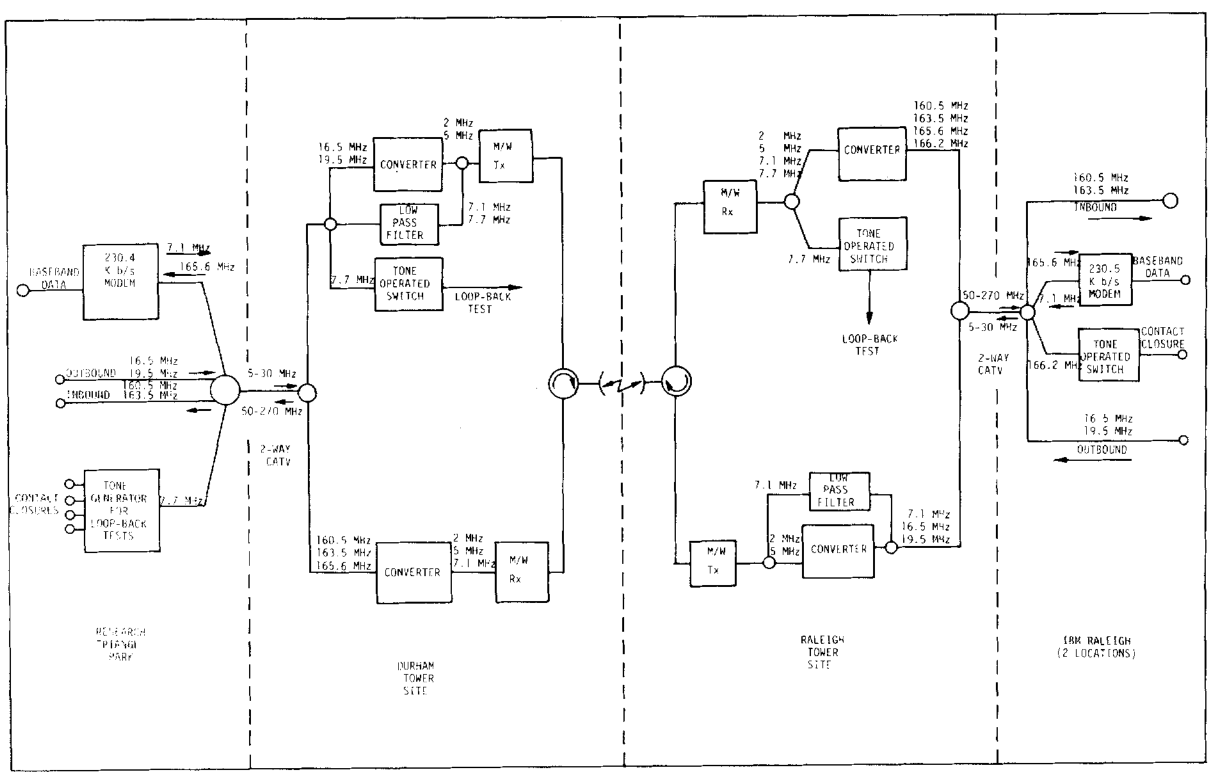


FIG. 2 DATA NETWORK INTERFACE BLOCK DIAGRAM

FSK data is impressed on the cable at 7.7 MHz to activate tone-controlled switches at the remote interface points, to perform loop-back tests.

The signals are carried via ATC's Durham CATV system in a subsplit configuration to the Durham microwave tower site. At this point, the 16.5 MHz and the 19.5 MHz signals are block converted to 2 MHz and 5 MHz, respectively, bandpass filtered, and presented to the baseband input of the microwave transmitter. The 7.1 MHz and 7.7 MHz carriers are low-pass filtered and combined with the 2 MHz and 5 MHz carriers at the baseband input to the transmitter. The 7.7 MHz carrier also feeds a tone decoder and switch, to perform a loop-back test between the microwave transmitter 70 MHz IF output and the microwave receiver 70 MHz IF input.

At the Raleigh tower site, the 2, 5, 7.1, and 7.7 MHz carriers are block converted to 160.5, 163.5, 165.6, and 166.2 MHz, respectively, and are transmitted via ATC's Raleigh CATV system to two IBM locations in Raleigh. Again, as was the case at the Durham tower site, the 7.7 MHz carrier also feeds a tone-operated switch, to effect a loop-back test from the microwave receiver IF output to the microwave transmitter IF input.

At both of the IBM locations in Raleigh, the 160.5 MHz and 163.5 MHz signals are introduced directly into the in-plant IBM coaxial network. The 165.6 MHz signal is demodulated by the 230.4 K b/s modem which provides baseband data output. The 166.2 MHz signal activates a switch which provides a contact-closure signal to IBM for testing purposes.

The transmission from the two Raleigh locations back to RTP is accomplished in a manner which is an almost exact "mirror-image" of the RTP-to-Raleigh path. However, no loop-back testing is needed. Therefore, no 7.7 MHz carrier or tone-activated switches are required in the Raleigh-to-RTP path.

The end-to-end link was tested to the specifications in Table 1, which are the specifications for IBM's in-plant network. Additionally, the link had to meet an end-to-end frequency offset of no more than ± 10 KHz. Link tests showed these specifications to be met.

The concept of terminal connections through a wideband coaxial channel is illustrated in Fig. 3. Although a dual cable representation is shown, the technique is also applicable to a single cable system using, for example, a mid-split frequency arrangement. The individual data channels on the cable are separated by Frequency Division Multiplex (FDM) techniques using selective RF digital modems.

Thus the Local Control Unit attached to Computer 1 transmits on carrier frequency f_a to its associated Remote Control Unit whose RF modem receives on frequency f_a. The reverse path data stream is on carrier frequency f_b. The terminals associated with Computer 2 operate on carrier frequencies f_c and f_d. They can therefore operate simultaneously with the terminals associated with Computer 1 over the same cables.

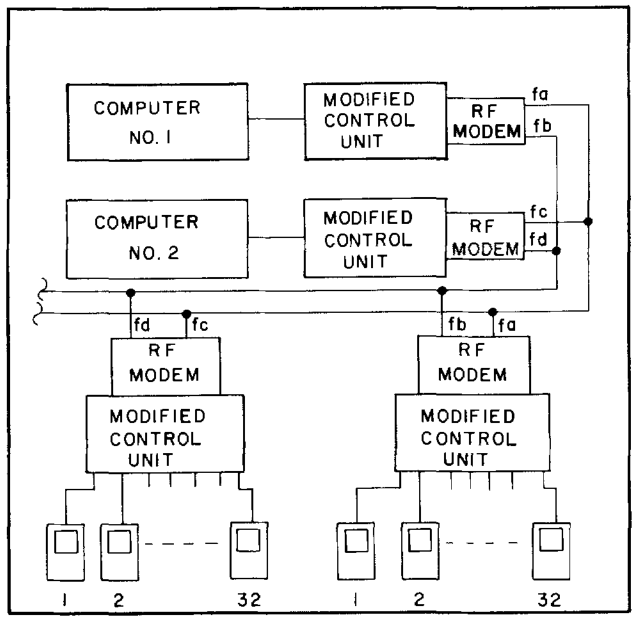


Fig. 3 Terminal Connections via FDM Techniques

Table I. In-plant Cable System Specifications

System impedance	75 ohms	Cross and inter-modulation full channel loading	-40 dB
Modem transmit carrier level	+50dBmV ± 2 dB	Channel flatness	1 dB peak to valley within ± 1.5 MHz of center frequency
Modem receive level	+10dBmV ± 10 dB	Radiation	Meets all U.S. and foreign standards
Modem carrier (rms)/ rms noise	40 dB over 3 MHz		
Echos relative to signal	-40 dB		

Each modem in the system occupies a channel 3 MHz wide. Use of these modems provides a theoretical maximum of approximately 88 channels over the dual-cable system, based on present CATV technology.

In order to implement the experimental system, some IBM terminal control units required modification. In addition, an RF, asynchronous, 1.2 M b/s modem was vendor-procured. Neither the control units nor the modems are available from IBM.

IN-PLANT CABLE SYSTEM

A dual-cable system, with 5-30 MHz and 50-300 MHz bandwidths in each direction, was chosen to be implemented. A vendor design was obtained for a complete network covering four of the major buildings at RTP and two locations in Raleigh. The initial precursor system as installed was a subset of the ultimate-coverage system, to allow orderly system expansion.

The site plan of IBM at RTP (Fig. 4) shows the main truck cabling and a portion of the link which eventually connects to the Raleigh location via the microwave link. The total cable length of the in-plant trunk system is about 22,000'.

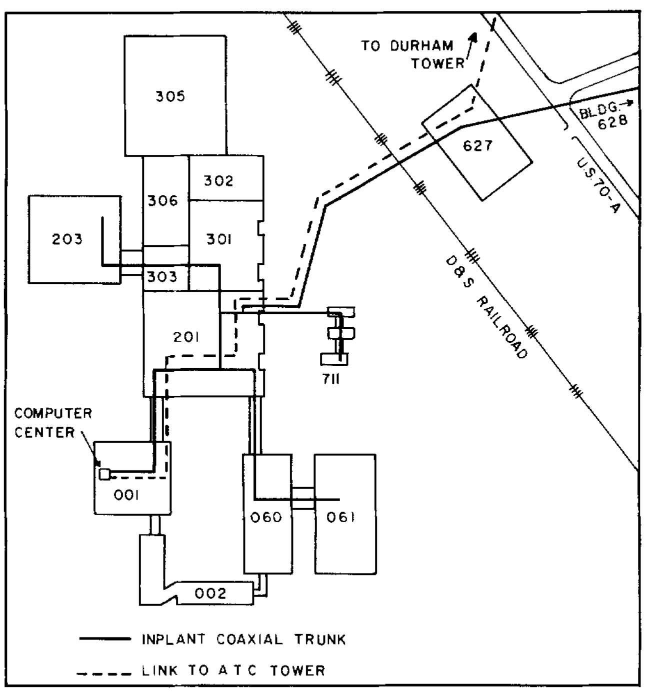


Fig. 4 RTP Coaxial Trunk System

The initial system requirements could have been met with a single cable, mid-split. However, because of the experimental nature of the technology program, it was decided to use dual cables. This provides the maximum bandwidth to accommodate (possible) future applications.

A typical portion of the cable distribution system within a building is shown in Fig. 5.

Standard CATV components are used throughout and the cable is the same as the trunk cable. Only the outbound network from the central computer has been shown. The parallel inbound cable system differs only in the direction of the amplifiers. Components used as splitters in the outbound network function as combiners in the inbound network.

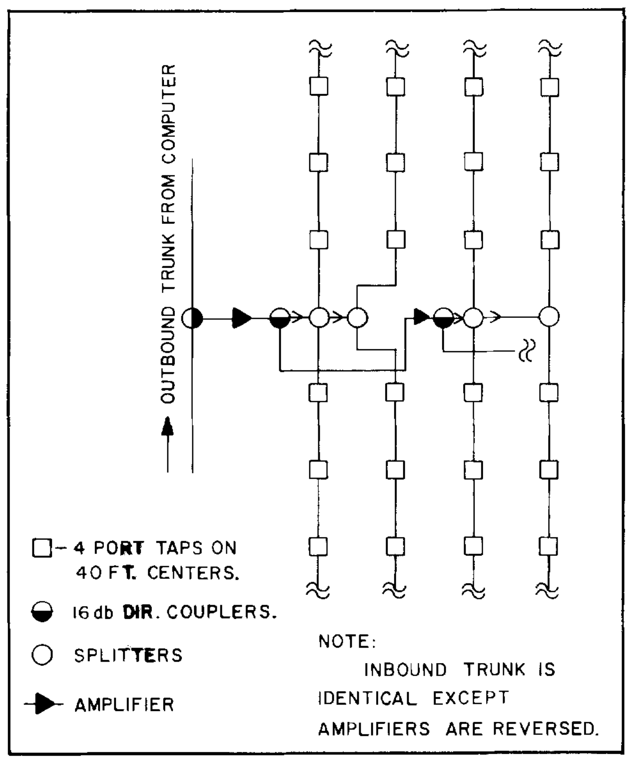


Fig. 5 Inplant Coaxial Distribution Network

The electrical specifications for the in-plant cable system, which also apply to the cable-microwave link, have already been shown in Table 1. These specifications were dictated primarily by the characteristics of the RF modem. Final system tests showed that these specifications were met.

SUMMARY

Both the in-plant and the microwave systems have been used in actual, not simulated, work environments for the past six months. Experience shows that these systems provide useful, reliable media for data transmission. However, there are basic differences between the home entertainment and the business environments which cannot be ignored.

Data applications usually require very high system reliability and availability. The first requirement implies the use of very high quality system components and meticulous construction practices. The second may require special system/maintenance agreements.

The growing use of data processing equipment implies a corresponding increase in the volume of data transmitted. Properly applied, the CATV and microwave technologies can be an important factor in this future business opportunity.

AN INTERCITY COAXIAL CABLE ELECTRONIC HIGHWAY

WILLIAM E. EVANS, JEFFREY C. ROHNE

MANITOBA TELEPHONE SYSTEM

ABSTRACT

Early in 1978 the Manitoba Telephone System announced its intention to proceed with the construction of a bi-directional coaxial cable intercity transmission network for the initial purpose of delivering television and FM broadcast signals to newly licensed CATV operators in more than twenty communities throughout southern Manitoba. This facility would provide a multi-purpose, user-shared "electronic highway" for the transmission of television, radio, data and new broadband telecommunications services.

The first 28 mile trunk was activated in February 1978 with the major 145 mile system from Winnipeg to Brandon placed in service on September 29. Performance test results using both frequency domain and baseband measurement techniques are presented along with operational experiences.

INTRODUCTION

In September of 1978 the Manitoba Telephone System (M.T.S.), placed in service a 171 mile broadband, bi-directional, coaxial cable transmission system linking Winnipeg, the province's capital and largest city, with Brandon, Manitoba' second largest city and three other major rural communities. This broadband "Electronic Highway" was designed for the transmission of CATV signals and various other broadcasting and telecommunications services to smaller rural cities and towns in southern Manitoba. The major initial users of the system, which is called the Intercity Broadband Network (ICBN), are newly-licensed CATV operators in the rural communities who are presently receiving U.S. network television and Winnipeg stereo FM signals via the ICBN for local distribution on coaxial cable within their communities.

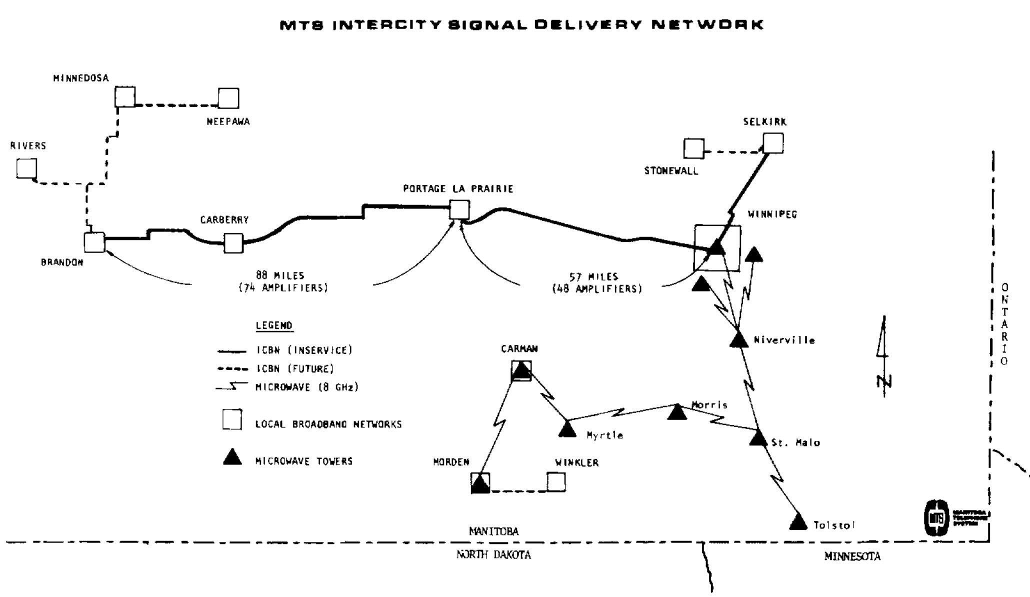


FIGURE 1

The capital cost of the ICBN highway is competitive with that of microwave radio for delivery of U.S. network CATV signals alone, with significant additional bandwidth being available for bi-directional transmission of telephony and other communications services.

A number of non-CATV services have already been transported on the highway with additional broadcasting and telecommunications services projected in the near future.

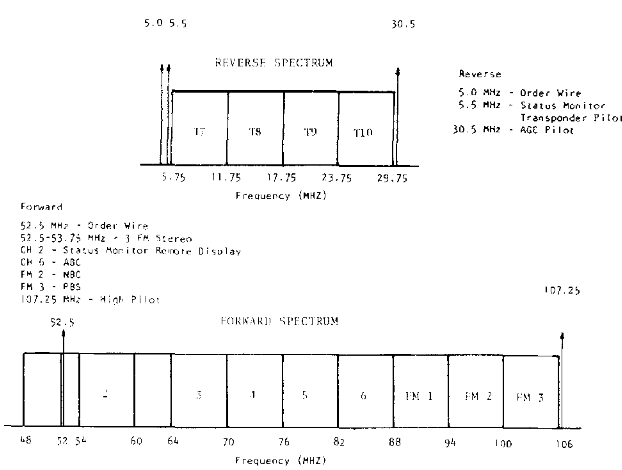
Extension of the present network to more than twenty additional communities in southern Manitoba is planned.

SYSTEM DESCRIPTION

At present the ICBN consists of two separate routes (Figure 1), a 26 mile, 23 amplifier system between Winnipeg and Selkirk, which has been operating for over one year, and a 145 mile western "highway" to Brandon which uses 122 cascaded amplifiers.

While standard CATV trunk systems normally are limited to approximately 30 miles by the buildup of noise and distortion from cascaded amplifiers, the ICBN employs a new "superlinear" amplifier to permit very good transmission over several hundred miles. The new amplifier, developed by Century III Electronics Inc., of Vancouver British Columbia, in response to M.T.S. specifications, utilizes the "feed-forward" technique for noise and distortion reduction.

The spectrum of the present system, shown in Figure 2, utilizes a "forward" transmission band of 50 to 108 MHz with "return" transmission occupying a band from 5 to 30 MHz. This spectrum plan permits forward transmission of up to 8 standard 6 MHz. television channels with return bandwidth equivalent to 4 such channels. Dual pilot



INTERCITY BROADBAND NETWORK SPECTRUM

Figure 2

carriers are employed in the forward transmission direction for automatic gain and slope control, with a single pilot Bode equalization system being used in the reverse direction.

Amplifier stations are generally spaced at 6300 feet with the coaxial cable being direct buried at a nominal depth of 40 inches. The soil conditions and terrain in Manitoba allow ploughing of cables at very favourable costs. Intermediate splices are located in special splice pedestals above ground such that future upgrade of the system can be made to higher operating frequencies and greater bandwidth capacity. For example, transmission up to 220 or even 300 MHz would be permissable by coverting all existing amplifiers to 300 MHz units and adding additional 300 MHz stations at the intermediate splice pedestals. While system noise and distortion performance would be degraded somewhat by the additional amplifiers, the additional bandwidth available for transmission would be substantial (as many as 35 standard 6 MHz television channels in the forward direction) and use of frequency modulation transmission techniques could be implemented to more than overcome the loss in transmission performance.

The superlinear amplifiers were designed to provide certain transmission performance parameters specified by M.T.S. engineers for a hypothetical 225 mile system. This system length would allow M.T.S. to serve virtually all of the populated, southern area of the province. Table 1 details the transmission performance over 225 miles that could be met using the superlinear amplifiers actually supplied and specified by Century III Electronics.

TABLE I
CALCULATED 225 MILE RESULTANT ICBN PERFORMANCE USING CENTURY III SUPERLINEAR AMPLIFIERS

SIGNAL TO NOISE RATIO (SNR)	45 dB
CROSS MODULATION DISTORTION (8 CHANNELS-PER NCTA 002-0267)	-64 dB
SECOND ORDER DISTORTION	-65 dB
HUM MODULATION (PER DOC BP-23)	-47 dB

With this ICBN transmission performance, CATV signals delivered to a Local Broadband Network (LBN), with its own noise and distortion degradation, would, at the worst-case CATV subscriber terminals, exceed in quality, the requirements of the Department of Communications, Broadcast Procedure 23 standards.

COMPONENT DESCRIPTION

The cable utilized for all presently installed systems is General Cable's Fused Disc 750 type cable, flooded and jacketed, which has proven to be able to withstand direct ploughing without any major difficulties.

A Century III superlinear amplifier station is shown in Figure 3. A modular approach was followed in design with a standard CATV trunk amplifier housing accomodating the forward (50-108 MHz) and reverse (5-30 MHz) amplifier modules. It is also equipped with a dual power supply module with automatic changeover, diplexing filters, AGC and ASC module and a microprocessor-based status monitor transponder. The performance specifications for the feed-forward (50-108 MHz) amplifier are listed in Table 2. The most noticeable specification improvement over high quality conventional trunk amplifiers is the dramatic decrease of approximately 30 dB in cross modulation distortion.

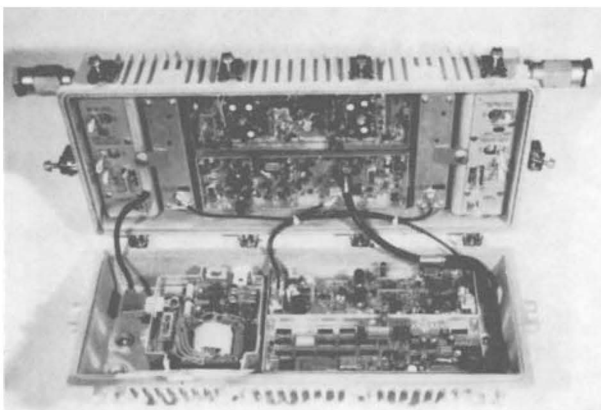


FIGURE 3

TABLE 2
FEEDFORWARD TRUNK AMPLIFIER
SPECIFICATIONS

FREQUENCY RANGE	45-110 MHz
FLATNESS	$\pm$0.15 dB
RETURN LOSS (ALL PARTS)	20 dB Min.
OPERATING LEVELS CH 2 110 MHz	 +43 dBmV +47 dBmV
GAIN (NOMINAL)	30 dB
CROSS MODULATION (8 CHANNELS-PER NCTA 002-0267)	-110 dB
TRIPLE BEAT	-120 dB
INTERMODULATION	-88 dB
HUM MODULATION (PER DOC BP-23)	-70 dB
NOISE FIGURE (0 dB EQLR)	7.5 dB

Reverse system performance is virtually identical to that of the superlinear forward package and by virtue of the light, four channel loading, the reverse amplifier does not have to employ the "feed-forward" technique.

The feed-forward module is, by its very nature, redundant. In fact it is very difficult to identify when one of the feed-forward gain blocks has failed since the increase in system noise and distortion is almost inperceptible. To facilitate identification of a failed chip an internal Amplifier Balance Check can be made on each station under the control of the status monitor terminal in Winnipeg. Under control of the amplifier microprocessor 4.8 KHz modulation is applied separately to the main and error amplifiers such that an ABC receiver will quickly indicate the measure of feed forward balance in that station under test.

An incident in October 1978 illustrates well the system "headroom" and tolerance for even major failures. A faulty amplifier connector introduced a 20 dB loss at the output of a system amplifier, yet system AGC and the substantial SNR margin in the system resulted in no visible signal degredation at the Brandon terminal. This tolerance can be used to advantage for restoration of service in that an entire amplifier section can be bypassed with flexible 412 cable with an overall SNR penalty of less than 3 dB.

Powering for the system is via the cable itself with power supplies located at a maximum of every 9 amplifier stations. The power supply, shown in Figure 4, is a special 105 volt quasi-square wave regulated unit built to meet M.T.S.

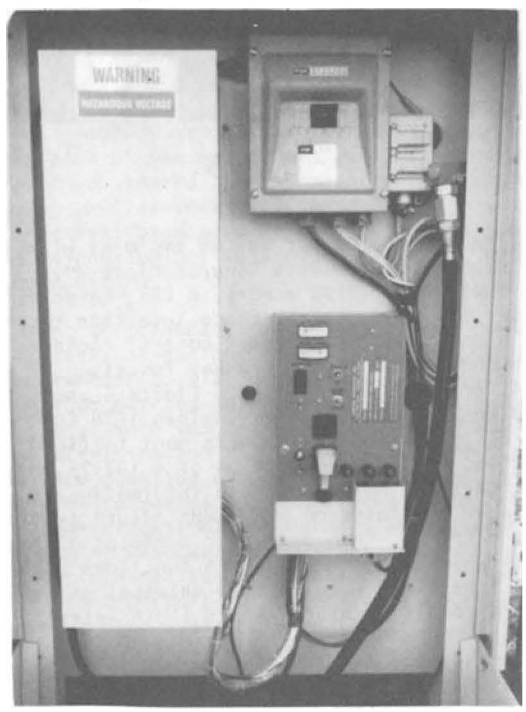


FIGURE 4

specifications by Sawyer Industries of California. Standby power, in the event of electrical utility outages, is provided by a battery bank and inverter, controlled by electronic logic. The supply achieves "no-break" standby powering thereby eliminating any "bumps" or switching transients.

Failure of primary power resulting in standby battery operation is sensed by the associated amplifier status monitor transponder and an alarm is conveyed to the control centre in Winnipeg.

Pedestals to house the amplifiers, mid-span splices and field power supplies were designed by M.T.S. and built by Inventronics Limited of Brandon, Manitoba. Figure 5 shows an amplifier pedestal (right foreground) with a larger power supply pedestal in the left rear. Climatic conditions in Manitoba, particularly frost heaving, necessitate extremely strong and stable pedestals and staking. With temperatures varying between -40°F and +95°F and winter frosts penetrating as deep as 7 feet, both electronic transmission and mechanical assemblies are severely tested.

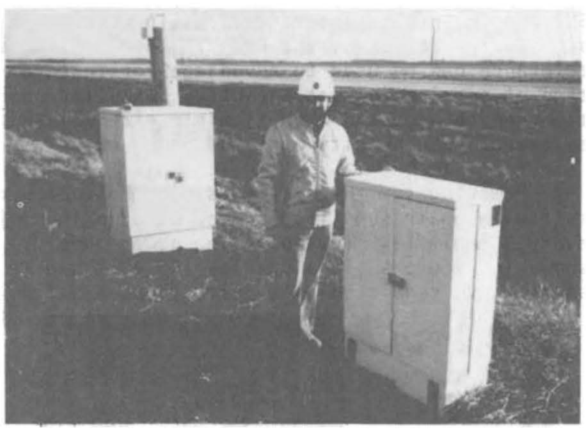


FIGURE 5

The status monitor system employed with the ICBN highway uses a Data General Micro Nova 3 with dual floppy disk memory, a CRT, hardcopy printer and a custom telephone interface to provide a comprehensive network control package which continuously monitors key functions at each amplifier and power station. Figure 6 shows the prototype terminal at the Winnipeg ICBN Control Centre. Interrogation data is sent to field locations via AFSK modulation of a 107.25 MHz pilot carrier, while response information is similarly modulated on a 5.5 MHz return system pilot carrier. Each amplifier contains a transponder which monitors analogue functions such as pilot levels and feed-forward balance, as well as failure condition alarm inputs (both internal and external to the amplifier), and power supply standby battery reserve measurement. Analogue inputs are digitized with all data continuously available to the control terminal. Automatic call out routines and various video and hardcopy information printouts are software features of the system. With the potential of several hundred amplifier stations being associated with the network, many located in remote locations, it is obvious that a sophisticated status monitor system is absolutely essential.

FIGURE 6

To facilitate communications and control from field locations, a portable multi-channel ICBN RF order wire was designed and built by M.T.S. engineers. This attache case-sized unit has 6 channel scanning with full duplex capability for voice communications, and a touch-tone pad for signalling and remote control. Touch-tones can be used to control functions on the network through the status monitor computer or to dial telephone numbers through an interface with the public switched-network.

U.S. Network CATV signals available in Winnipeg at video baseband are modulated into the ICBN using Scientific Atlanta 6350 modulators manufactured for ICBN channel assignments. At M.T.S. Toll Offices in each of the rural communities special Scientific Atlanta 6150 processors convert the CATV signals to the VHF channel assignments licensed to the local CATV operator. These signals are then distributed to the CATV subscribers on the M.T.S. Local Broadband Network (LBN). Provision is made with the processors for the use of chroma delay equalizers. Chroma delay distortion is not a problem with the higher forward channels presently in use but equalization will be necessary on channels closer to 50 MHz.

TRANSMISSION PERFORMANCE

The availability of a new Tektronix 1450 demodulator allowed transmission testing of SNR crossmodulation, intermodulation and hum modulation to be done at baseband, using standard telephone industry video test procedures. These key parameters were also tested using the RF techniques common to the CATV industry, through use of Hewlett Packard 8553 and Tektronix 7L13 spectrum analyzers, Dix Hills R-12/5X-16 system and accessories.

Comparison of RF with baseband measurements of *major parameters proved to be very gratifying. There was very close agreement (within 1 dB) between the results independently measured using* each technique.

Figure 7 shows the acceptance testing underway at the Brandon ICBN terminus.

FIGURE 7

Table 3 details the overall test results respectively.

TABLE 3
WINNIPEG-BRANDON ICBN
OVERALL TEST RESULTS
145 MILES - 122 AMPLIFIERS

SIGNAL TO NOISE RATIO (WORST CASE)	53 dB
CROSSMODULATION (8 CHS-PER NCTA 002-0267)	<-66 dB
HUM MODULATION (PER DOC BP-23)	-51 dB
INTERMODULATION	<-80 dB
FREQUENCY RESPONSE	±0.3 dB
LINE TIME DISTORTION	2% Max.*
PULSE TO BAR RATIO	*3% Max.**
2T PULSE SHAPE (K FACTOR)	2% Max.*
LUMINANCE NON-LINEARITY	2% Max.*
SYNC COMPRESSION	2.5% Max.*
CHROMINANCE GAIN NON-LINEARITY	4% Max.*
DIFFERENTIAL GAIN	2% Max.*
DIFFERENTIAL PHASE	1% Max.*

It should be noted that careful baseband testing of the modulators in Winnipeg clearly established that the baseband test values (asterisk) were established by the origination modulator-Tektronix demodulator combination and that there was no measurable degradation of these parameters by the ICBN transmission system.

INTEGRATED SERVICES

While there are many interesting aspects to the new technology associated with ICBN, the most exciting side of the network is its role as a multi-purpose, shared user, broadband electronic highway. In six months of operation it has already demonstrated several unique service applications beyond the delivery of CATV service to rural communities.

During the Canada Winter Games, a two week athletic event of national interest, held this year in Brandon, coaxial cable facilities including the ICBN carried daily live video and audio originations which fed the national French and English television and radio networks of the Canadian Broadcasting Corporation (CBC), an organization respected throughout the world for its stringent technical standards. Every second of programming was carried to some extent by coaxial cable with ICBN being used in the reverse direction to transport four 15 KHz audio circuits to Winnipeg which distributed daily programming across Canada. Catel FM modems were used on the ICBN and the Brandon LBN for audio and some video transmission. Scientific Atlanta modulators/demodulators handled the rest of the video transmission.

The private CTV network affiliate in Winnipeg operates a network of seven rebroadcasting stations in western and northern Manitoba. ICBN facilities have been used to carry special programming from Winnipeg to western Manitoba for this broadcaster.

Stereo FM transmission on the ICBN highway is particularly cost effective. Those familiar with telephony will recognize that stereo transmission on message facilities requires two full "groups" of channels with precise phase differential and amplitude equalization. Such facilities are very costly compared to ICBN which can transport the stereophonic signals either in encoded format or as separate left and right channels with excellent gain-frequency response, distortion and noise characteristics. At present four Winnipeg stereo FM stations are on the ICBN with strong possibilities existing that more will be added. The CBC, apparently pleased with performance during the Winter Games, has recorded its interest in further investigating ICBN for the transmission of network signals to Brandon on a full time basis.

While telephony transmission on coaxial cable has been successfully trialed by various organizations, and is providing message service near Rimouski,Quebec to customers of the Quebec Telephone System, most approaches to telephony on coax have married the digital PCM format with existing CATV AM or FM modems in a satisfactory, but bandwidth inefficient manner. Theoretical calculations, reinforced by careful testing and monitoring, have indicated that ICBN is capable of high capacity (up to 1200 message channels in 6 MHz bandwidth) telephony transmission using standard AM suppressed carried techniques. An AM SSBSC modem specification has been issued to a number of CATV and telecommunications manufacturers soliciting techno-economic response regarding manufacture of such a unit. M.T.S. is carefully evaluating competitive costs of providing additional required message circuits in all areas of Manitoba using conventional techniques, coaxial cable and fibre optics, with a recognition of future broadband service requirements.

It is anticipated that the imminent usage of Canadian satellites to deliver additional programming services to CATV subscribers will prove to be a stimulus to ICBN usage. Ground receive station costs in Canada are, for a variety of reasons, significantly higher than in the United States and the most cost effective way of distributing satellite signals to small rural communities may be via ICBN from satellite receivers established in the larger centres. At present, delivery of the live proceedings of the Canadian House of Commons to rural CATV operators is being considered using ICBN from a ground receive station in Winnipeg.

Similarly there is great interest concerning possible delivery of live proceedings of the Provincial Legislature to rural communities using ICBN.

With the coaxial cable facilities in Winnipeg being used by M.T.S. to distribute full time bi-directional medical information between two major hospitals in Winnipeg, and the existance of a large 2.5 GHz information retrieval ETV system with a major software library, in suburban Winnipeg, there are major opportunities for extension of medical and educational television services to provincial communities on, or near the electronic highway.

Presumably other new futuristic services such as Videotex, alarm and meter reading, teleshopping, facsimile, electronic mail and electronic newspapers could be distributed on the multi-purpose, multi-user electronic highway.

CONCLUSION

While fibre optics technology (FOTS) has generally been advanced by the common carriers as the means of providing the shared-user, multiservice communications "electronic highway", the Manitoba Telephone System has established a medium haul facility in southern Manitoba using coaxial cable which is already assuming "electronic highway" stature with the promise of more to come in the near future. While the existing coaxial system is likely to serve user needs for many years, it can be expanded substantially in capacity with minimal additional cost. The physical electrical and logistical tests provided by this operating facility are almost identical to those which will be critically important to future fibre optics systems, particularly in the severe Manitoba climate.

The development of a superlinear broadband "feedforward" amplifier which was paramount to the success of this project will have important consequences for all segments of the CATV industry in that development by its manufacturer is well advanced on a 300 MHz unit which will provide dramatic improvements in system transmission performance, and the economics of local distribution. This progress is particularly important at this time when cabling of the larger American cities, with required lengthly trunk amplifier systems, appears to be on the horizon.

The development of a sophisticated status monitoring system with expansive software capabilities, a new 105 volt "no-break" standby power supply, a new series of rugged pedestals, and a multi-channel, portable, full-duplex telephone for use on bi-directional coaxial cable systems are important and interesting side-benefits associated with the ICBN.

Most important, interesting and cost effective new integrated applications have already and will continue to be established for coaxial cable technology using the M.T.S. ICBN.

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ANALYSIS AND MEASUREMENT OF CATV DROP CABLE RF LEAKAGE

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ABSTRACT

The coupling of electromagnetic fields through CATV drop cables can be measured using a Radiometer. The theoretical analysis of this coupling, which began in 1934, is reviewed and the measurements agree with the predictions. Accordingly engineers can theoretically analyze and design coaxial cables. The measurements show that the different types of drop cables in use result in a large variation in coupling. The flexure measurements show that some cables would be expected to have 10 times longer flexure life than other types.

INTRODUCTION

The theoretical development of electromagnetic field coupling through the shields of coaxial cable began many years ago. The general theory was presented in an article by Schelkunoff in 1934 (1). He represented the coupling by a transfer impedance and developed formulae for calculating the characteristics of solid shields. He also analyzed multiple-layer shields. Since 1934 numerous people have analyzed the coupling mechanisms and methods of measuring the coupling.

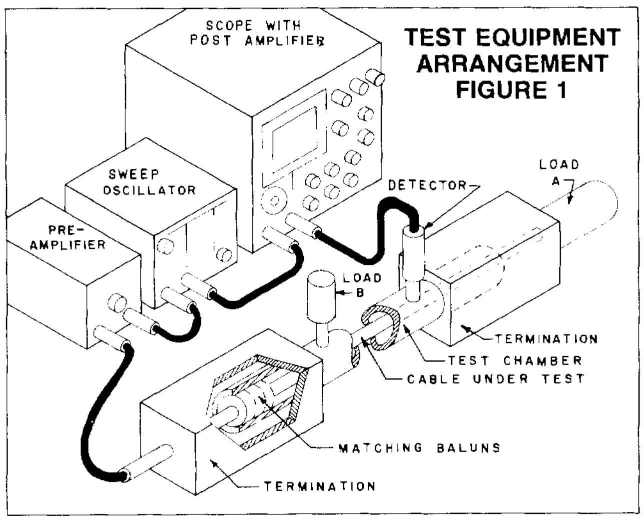
This paper will reference the following: Vance's article (2) presented in 1975, which develops the transfer impedance and transfer admittance of braided-wire shields based on the theory of coupling through electrically small-irises developed by Kaden (3) and Marcuvitz (4). In 1974 the International Electrotechnical Commission's Working Group 1 (Screening Efficiency) accepted a United Kingdom proposal presented by Fowler (5), to express the transfer admittance by a capacitive impedance quantity which the IEC called "Capacitive Coupling Impedance". At the Aneheim, California, NCTA Convention in 1973 Ken Simons gave a presentation titled "A Shielding Effectiveness Measuring Jig for CATV Cables". He also presented a paper (6) to the IEC sub-committee 46A (Radio-Frequency Cables) titled "The Terminated Triaxial Test Fixture". Ken describes a test fixture and test method for measuring transfer impedance and capacitive coupling impedance. Ken's work was an extension of Zorzy's work (7) presented in 1961. Early work was performed on this triaxial test method by Ochem in 1936 and is described in an historical summary by Bourseau and Sandjivy (8). In 1978 Times Wire and Cable developed and started marketing an instrument called a Radiometer for measuring the transfer impedance and capacitive coupling impedance which uses the triaxial test method.

The purpose of this paper is to show the transfer impedance and capacitive coupling impedance of different types of CATV drop cables. The theory of electromagnetic field coupling and method of measurement will be reviewed. The measurement data on different types of drop cables will be given and the change resulting from flexure of the cable will be shown.

MEASUREMENT

The Radiometer measures the absolute value of the transfer impedance and capacitive coupling impedance of the coaxial shield.

An artist sketch of the test set-up is given in Figure 1. The coaxial cable is coaxially supported by a dielectric in the test chamber creating a triaxial transmission system. The inner coaxial transmission system is inside the test specimen. The outer coaxial transmission system's center conductor is the specimen's shield and its outer conductor is the test chamber. The specimen is terminated in its characteristic impedance by load A and the combination of the sweep oscillator and preamplifier. Load B and the detector are



TEST EQUIPMENT ARRANGEMENT FIGURE 1

connected to the outer system by coaxial terminals. The rectangular termination on the ends of the chamber have ferrite toroids surrounding the test sample. These toroids minimize current flow along the shield of the test specimen to the end of the rectangular termination where the shield of the specimen is grounded. These rectangular terminations form "baluns" creating a high impedance allowing the load B and detector to match the impedance of the chamber. Errors are not introduced by leaky connectors; the shield of the specimen is unbroken through the entire length of the fixture. The connectors on the sample are connected to the ends of the rectangular terminations and are not critical since the "baluns" isolate the connector's leakage from the signal in the test chamber.

When the equipment is set up as shown in Figure 1, an analysis, neglecting attenuation and assuming the cable shield is uniform, shows that the magnitude of the output voltage in the triaxial transmission system is:

$$|V_f| = \left| \frac{(Z_t - Z_f)\, V_i \sin[(\beta_s - \beta_c)\, L/2]}{Z_s\, (\beta_s - \beta_c)} \right|$$

Where V_f = The detector voltage with set up of Figure 1
V_i = The specimen input voltage
Z_t = The transfer impedance in ohms per meter
Z_f = The capacitive coupling impedance in ohms per meter
L = The distance between the coaxial terminals of the test chamber in meters
Z_s = The specimen characteristic impedance in ohms
β_s = The specimen phase constant in radians per meter
β_c = The test chamber phase constant in radians per meter

An analysis of the output voltage with Load B and detector exchanged shows:

$$|V_R| = \left| \frac{(Z_t + Z_f)\, V_i \sin[(\beta_s + \beta_c)\, L/2]}{Z_s\, (\beta_s + \beta_c)} \right|$$

Where V_R = The detector voltage with Load B and detector swapped

Z_t and Z_f may be calculated, since the ratios V_f/V_i, V_R/V_i, β_s, β_c, L, and Z_s can be measured. The test procedure provided with the Radiometer includes tables which can be used to convert the voltage ratios measured in decibels to transfer impedance and capacitive coupling impedance. The minimal specimen attentuation is neglected but the chamber attentuation is accounted for. The tables were obtained from the following equations:

$$Z_t = \frac{1}{L} \sqrt{Z_s Z_c} \left(\left|\frac{\phi}{\sin \phi}\right| e^x + \left|\frac{\theta}{\sin \theta}\right| e^y \right)$$

$$Z_f = \frac{1}{L} \sqrt{Z_s Z_c} \left(\left|\frac{\phi}{\sin \phi}\right| e^x - \left|\frac{\theta}{\sin \theta}\right| e^y \right)$$

Where Z_t = The transfer impedance in ohms per meter
Z_f = Capacitive coupling impedance in ohms per meter
Z_s = The specimen characteristic impedance in ohms
L = Chamber length in meters

$\phi = (\beta_s + \beta_c)\, L/2$ in Radians
$\theta = (\beta_s - \beta_c)\, L/2$ in Radians
Z_c = The chamber characteristic impedance in ohms
β_s = Specimen phase constant in radians per meter
β_c = Chamber phase constant in radians per meter

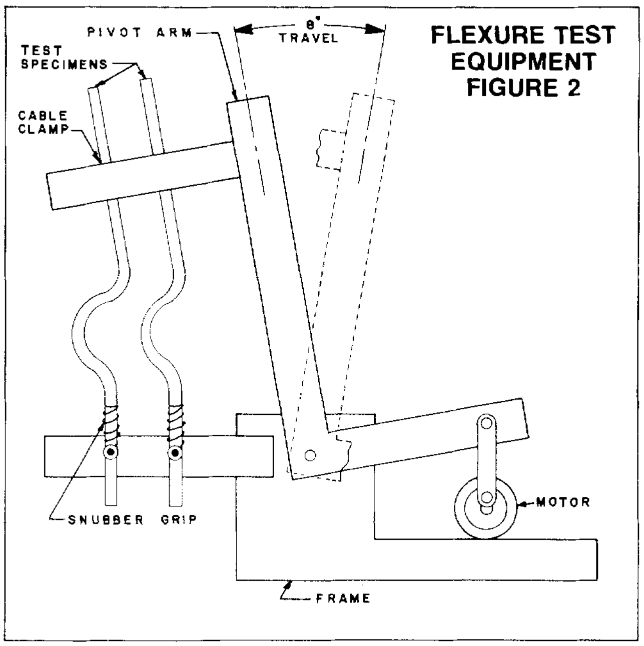
$$x = \frac{DB_R - \alpha_c/2}{8.68} = \ln V_R/V_i$$

$$y = \frac{DB_F - \alpha_c/2}{8.68} = \ln V_F/V_i$$

α_c = Chamber attentuation
Note: X, Y, DB_R, DB_F and α_c are negative quantities.

TEST RESULTS

The transfer impedance and capacitive coupling impedance of the shields can degrade in service as a result of flexure. A test similar to the following is commonly performed, throughout the industry, to evaluate the flexure characteristics: Initial transfer impedance and capacitive coupling impedance is measured. Then the samples are wrapped 360 degrees around a mandrel whose diameter is five (5) times the outer diameter of the cable. The two ends of the specimen are held while the mandrel is moved down the cable length then returned to the starting point. This flexure is repeated five times, then the cable is reverse bent 360 degrees around the mandrel and the flexure repeated. After this flexure it is found that the transfer characteristics from some cables which have a dry foil with a braid over it, increase 40 times. By contrast, a cable with sealed foil - 60% braid - foil - 40% braid shield shows a comparatively small change in transfer characteristics when subjected to the same test. In general, before flexure, the sealed foil constructions have higher transfer characteristics than dry foils. However, after flexure the sealed foils have lower transfer characteristics than dry foils.

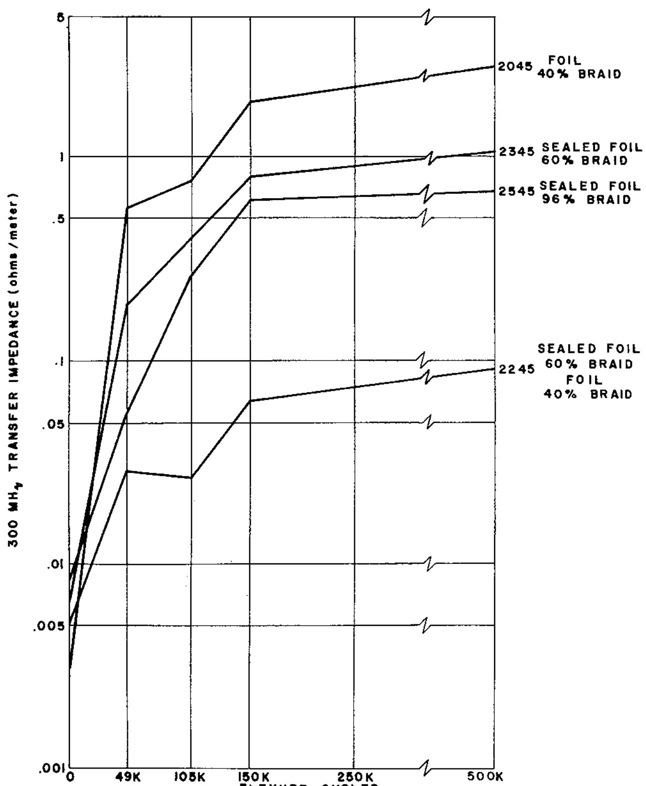


FLEXURE TEST EQUIPMENT FIGURE 2

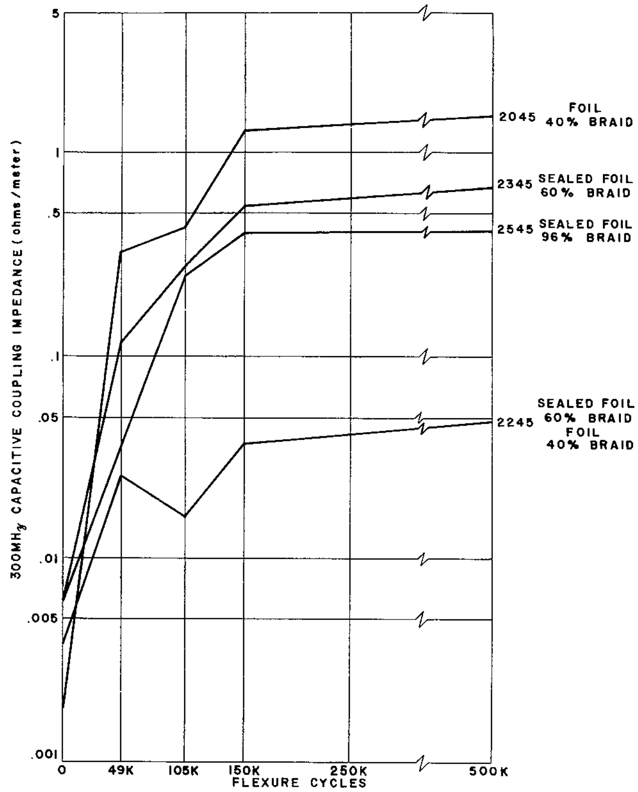
These flexure results are very meaningful but the flexure does not represent the flexure in service. New flexure data was taken using the equipment illustrated in Figure 2. The cables are flexed at a rate of 40 cycles per minute. One flexure cycle is plus and minus 8 degrees travel. The transfer characteristics were measured initially then after different flexure cycles. The highest increase in transfer characteristics occurred at 300 MHz, therefore, this data is plotted versus flexure cycles in Figures 3 and 4. Only limited data has been taken, one sample for each type cable shown. The data confirms that after flexure the sealed foils have lower transfer characteristics than dry foils. As would be expected, the sealed foil - 60% braid - foil - 40% braid type does eventually degrade but it has far longer life than the other constructions. It appears that the flexure life of this cable is 10 times that of all other cable types tested.

The average transfer impedance and capacitive coupling impedance test data, measured on random samples of cable manufactured by Times Wire and Cable, is plotted in Figures 5 thru 10. Except for Times Wire and Cable MI-2245, measurements have been performed to confirm that the cable performance is typical for the same type of cable manufactured in general by industry. To my knowledge Times Wire and Cable is the only company manufacturing a cable with the construction of MI-2245 which has a sealed foil - 60% braid - foil - 40% braid shield.

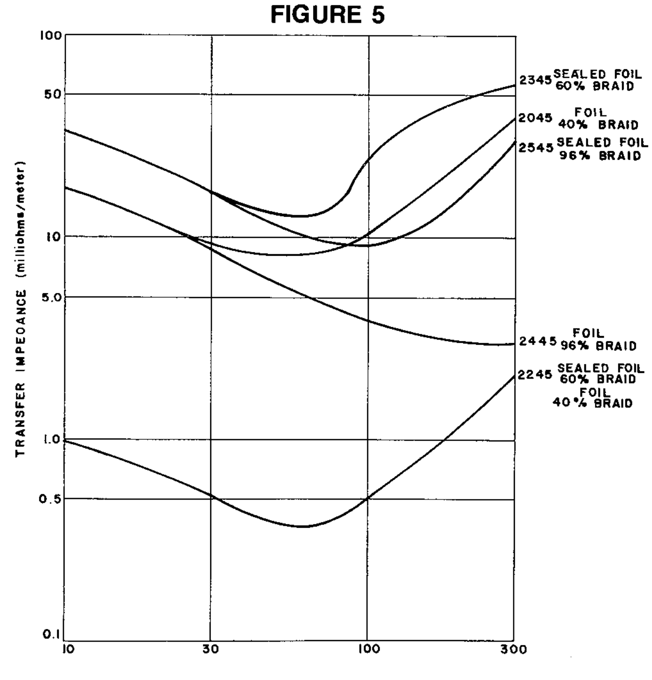
RG-59/U TYPE
300 MHz TRANSFER IMPEDANCE
VERSUS FLEXURE CYCLES
FIGURE 3



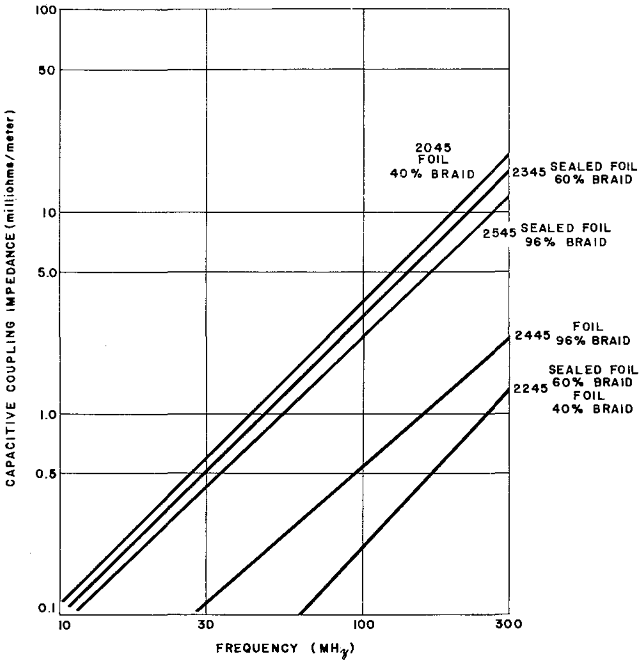
RG-59/U TYPE
300MHz CAPACITIVE COUPLING IMPEDANCE
VERSUS FLEXURE CYCLES
FIGURE 4



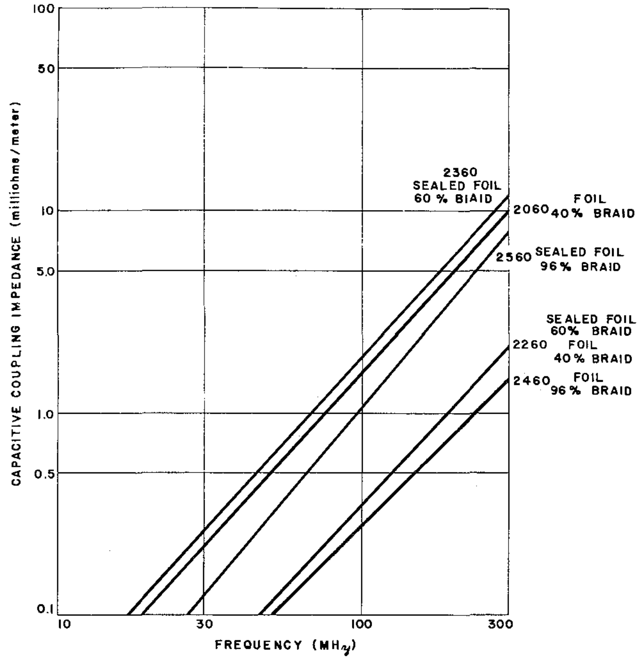
RG-59/U TYPE
TRANSFER IMPEDANCE
VERSUS FREQUENCY
FIGURE 5



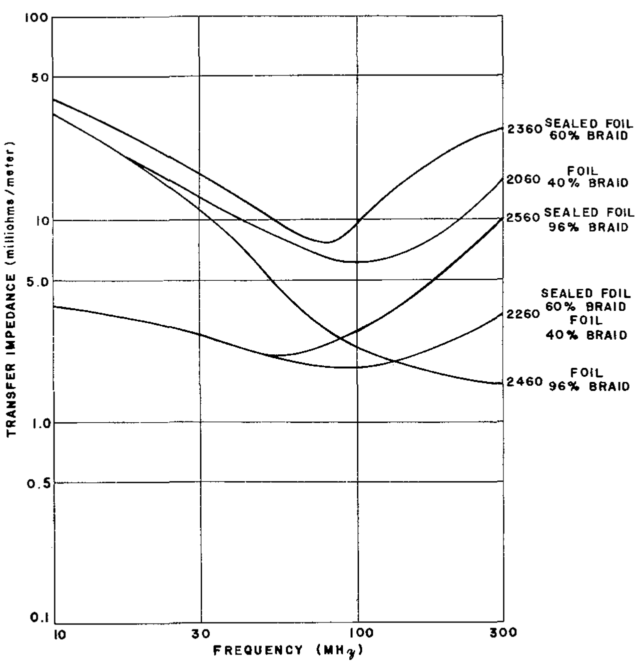
RG-59/U TYPE
CAPACITIVE COUPLING IMPEDANCE
VERSUS FREQUENCY
FIGURE 6



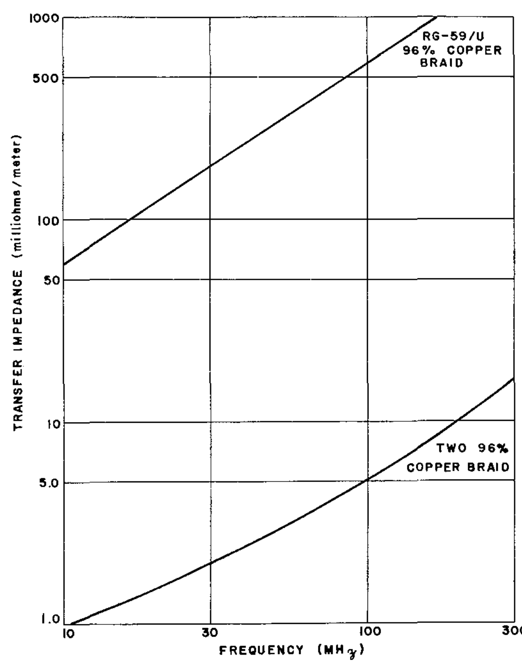
RG-6/U TYPE
CAPACITIVE COUPLING IMPEDANCE
VERSUS FREQUENCY
FIGURE 8



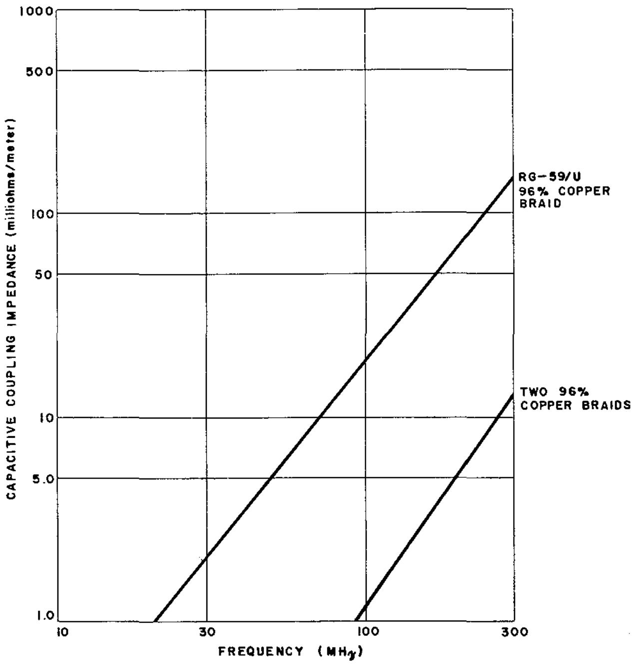
RG-6/U TYPE
TRANSFER IMPEDANCE
VERSUS FREQUENCY
FIGURE 7



BRAIDED SHIELDS
TRANSFER IMPEDANCE
VERSUS FREQUENCY
FIGURE 9



BRAIDED SHIELDS
CAPACITIVE COUPLING IMPEDANCE
VERSUS FREQUENCY
FIGURE 10



DISCUSSION AND ANALYSIS OF TRANSFER IMPEDANCE TEST RESULTS

Transfer impedance is defined in an elementary length of coaxial cable as the ratio of the potential gradient (voltage) in the disturbed circuit to the current flowing in the interfering circuit. When the cable is acting as a transmitting antenna (egressive signals) the disturbed circuit is the environment around the cable. When the cable is acting as a receiving antenna (ingressive signals) the disturbed circuit is within the cable and the interfering circuit is the environment around the cable. A lower transfer impedance reduces the electromagnetic coupling (radiation).

The transfer impedance of a braided shield has two components; a diffusion component caused by current diffusing through the metal and a mutual-coupling component caused by penetration of the magnetic field through the openings in the braid. The mutual-coupling component can be represented by a mutual inductance.

The transfer impedance is the vector sum of these two complex quantities and its magnitude is:

$$|Z_t| = \sqrt{(|Z_d| \cos \phi)^2 + (|Z_d| \sin \phi + |Z_m|)^2}$$

Where $\phi = .785 - \tan^{-1} (\coth d/\delta \tan d/\delta)$
Z_d = The diffusion component of Z_t in ohms per meter
Z_m = The mutual-coupling component of Z_t in ohms per meter
d = The diameter of braid wire in meters
δ = The skin depth in meters

The approximate diffusion component and mutual-coupling component for braided cable is obtained from an extension of Vance's equation (2) and Schelkunoff's (1):

The diffusion component is:

$$|Z_d| = R_{dc} \frac{(\sqrt{2})\, d/\delta}{\sqrt{\sinh^2 (d/\delta) + \sin^2 (d/\delta)}}$$

$$\delta = \sqrt{\frac{\rho}{\pi f \mu'}}$$

The mutual coupling is:

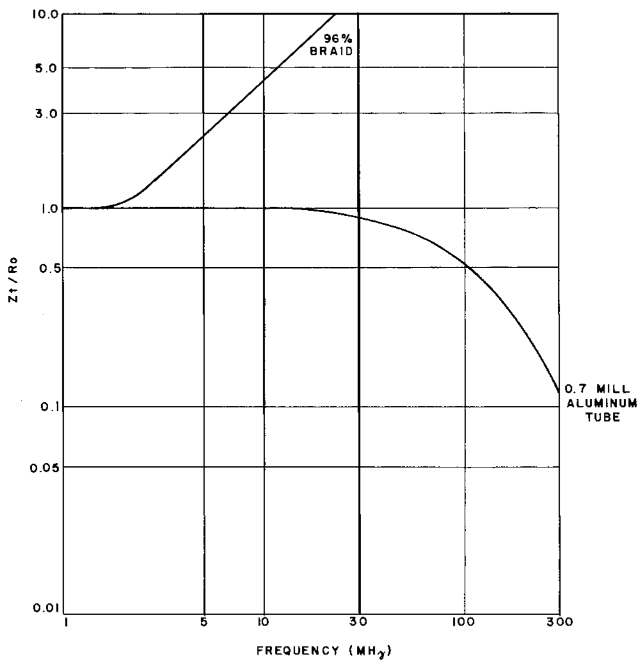
$$|Z_m| = \frac{\omega v \mu m}{\pi^2 D^2}$$

Where ρ = The resistivity of the shield in ohm-meters
f = The frequency in hertz
μ' = The absolute magnetic permeability of the shield in henries per meter
d = The diameter of braid wire in meters
R_{dc} = The dc resistance of the shield in ohms per meter
ω = The angular frequency in radians per second = $2\pi f$
v = The number of holes per meter in the braided shield
μ = The absolute magnetic permeability of the insulation between the conductors in henries per meter
D = The mean inside diameter of the shield in meters
m = The magnetic polarizability of the holes in the braid (2)
Z_m = Mutual-coupling component in ohms per meter
Z_d = Diffusion component in ohms per meter
δ = Skin depth in meters

The magnetic and electric polarizability of holes in a braid can be determined experimentally using electrolytic-tank techniques (7). Vance obtained the polarizability of the diamond-shaped hole by calculating the polarizability of an equivalent elliptical hole (2).

The only fields that transfer through solid shields are those that diffuse through the metal. The preceding equation for the diffusion component is the equation for the transfer impedance of solid shields when "d" is equal to the shield thickness. The theoretical transfer impedance divided by the dc resistance of braided and solid shields versus frequency is plotted in Figure 11.

**COAXIAL CABLE
TRANSFER IMPEDANCE (Zt) DIVIDED
BY SHIELD D.C. RESISTANCE (Ro)
VERSUS FREQUENCY
FIGURE 11**



Comparing the test data plotted in Figure 9 with the theoretical curves of Figure 11 shows the RG-59/U cable with a braided shield performed as predicted by the theory for a braid. The constructions of Figures 5 and 7 have shields which are layers of foils and braids. Since the foil completely surrounds the dielectric it might be expected that there would be no openings in the shield allowing mutual-coupling. Therefore, the cable would perform like a tube. The cables do show the tube characteristics except at the higher frequencies where the transfer impedance begins to increase. The cause of this increase is that there are openings at the foil overlap and some mutual-coupling does exist.

The test data presented is for foam polyethylene dielectrics, data on solid polyethylene dielectrics show somewhat lower transfer characteristics. This would be expected since the dielectric is harder and more pressure may be applied by the braid shorting out the overlap.

The sealed foil-60% braid-foil-40% braid construction has the lowest initial transfer characteristics as would be predicted, since the shield has a sealed foil on the dielectric then a dry foil sandwiched between two braids. The braid on both sides of the foil shorts out the foil overlap far better than a braid on only one side. The large amount of metal in the shield results in low transfer characteristics at low frequency caused by low shield resistance and low diffusion of current through the shield. The sealed foil constructions have adhesive on the foil overlap; therefore it causes higher initial transfer characteristics than obtained with foils which have no adhesive.

Flexure causes an increase in the opening at the foil overlap and/or fractures the foil, increasing the mutual-coupling (transfer impedance). The sealed foil constructions adhere the foil to the dielectric and the foil to foil overlap, minimizing the flexure effect on the foil. Flexure has the least effect on the sealed foil-60% braid - foil - 40% braid construction due to the braid on both sides of the foil shorting out the opening at the tape overlap, and it also has two layers of foils and braids.

ANALYSIS OF CAPACITIVE COUPLING IMPEDANCE TEST RESULTS

The openings in the shield also allow the electric field to penetrate creating electric coupling. This coupling can be represented by a capacitive coupling between the center conductor of the coaxial cable and the return path external to the cable.

The capacitive coupling impedance is derived from the definition accepted by the International Electrotechnical Commission Working Group 1 (Screening Efficiency) (5) and Vance's equation for transfer admittance (2).

$$Z_f = \frac{p}{m} Z_m \sqrt{\epsilon_{re}/\epsilon_{ri}}$$

Where Z_f = The capacitive coupling impedance in ohms per meter
p = The electric polarizability of the holes in the braid (2)
m = The magnetic polarizability of the holes in the braid (2)
Z_m = The mutual-coupling component of Z_t in ohms per meter
ϵ_{re} = The relative dielectric constant of the insulation in the external circuit
ϵ_{ri} = The relative dielectric constant of the insulation within the cable

The capacitive coupling impedance will be zero if there are no openings in the shield. If there are openings, then the capacitive coupling impedance should vary directly with frequency. The test data plotted in Figures 6, 8 and 10 follows this characteristic reasonably well.

CONCLUSIONS

The transfer impedance and capacitive coupling impedance of coaxial shields can be measured and the results agree with the theoretical equations. Since the theory of transfer of energy through shields is known, an engineer can theoretically analyze and design coaxial cable.

The different types of drop cables in use today results in a large variation in the coupling of electromagnetic fields through the shields. The RG-59/U drop cable, with a 96% braid, has a transfer impedance at 300 MHz, 1000 times higher than a sealed foil - 60% braid - foil - 40% braid cable. It also has a capacitive coupling impedance at 300 MHz, 400 times higher. The sealed foil - 60% braid - foil - 40% braid cable was the only cable type tested that had a low 5 MHz transfer impedance (.001 ohm per meter), yet all constructions have negligible 5 MHz capacitive coupling impedance.

The type of cable to be used can not be chosen based only on cable performance before installed in a system. The performance after flexure must be considered; flexure life is a very important consideration. It appears that the flexure life of the sealed foil - 60% braid - foil - 40% braid is 10 times that of all other cable types tested.

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CALCULATION AND BALANCE TECHNIQUE FOR
A SMALLER DEDICATED RETURN LINE

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Abstract

Many systems are using or considering using a return signal path on at least a part of their normal cable system. This paper presents some of the calculations and balance techniques which may be used in setting up a smaller, dedicated line. It does not include the complex task of balancing a large fully implemented two-way system.

Techniques presented include the use of one carrier, two carriers, and sweep methods. Discussions on thermal compensation includes pilot carrier AGC and thermal equalizers. Some comments on data transmission will also be made.

Introduction

The large scale two-way systems have received a lot of publicity and indeed have been responsible for innovative designs and technology improvements. However, the majority of two-way systems in actual operation are small dedicated runs, usually from the office to the headend or similar point-to-point networks. Large systems require extensive planning, design, and sophisticated balancing techniques. The single, most troublesome, feature of two-way systems is the combining of sub-trunks. When sub-trunk returns are combined and the span lengths are different, the problem of achieving compatible levels is very difficult and leads to complex balancing procedures. Single dedicated return runs without sub-trunk returns can be balanced relatively easily in several ways. Some system calculations must be made to determine levels, equalization, and module gains.

This paper assumes that the forward system has been designed and possibly built.

System Functions

The first step is to define the system function regarding its use. Several possible conditions are listed in Table 1.

1. Single video channel
2. Multiple video channels
3. Single data channel
4. Multiple data channels
5. Combination video and data

TABLE 1 POSSIBLE SYSTEM FUNCTIONS

These operational functions will determine the bandwidth, the required stability, and possibly the balancing technique to be used. Video channels will require a more stable operation than data channels. If the cascade is short, thermal equalizers may be sufficient. On longer cascade, an AGC system may be required. Multiple video channels will require a more accurate set up than either a single channel or data-only system.

Next, determine whether to inject the return signal directly into the trunk, directly into the distribution cable, or through a directional tap.

The simplest system results when the return signal is injected directly into the trunk through a suitable directional coupler. This, naturally, eliminates the set up of the distribution line but necessitates disturbing the trunk with possible down time.

Distribution lines are much more forgiving of disturbances but will require the additional set up of line extender reverse modules. The least

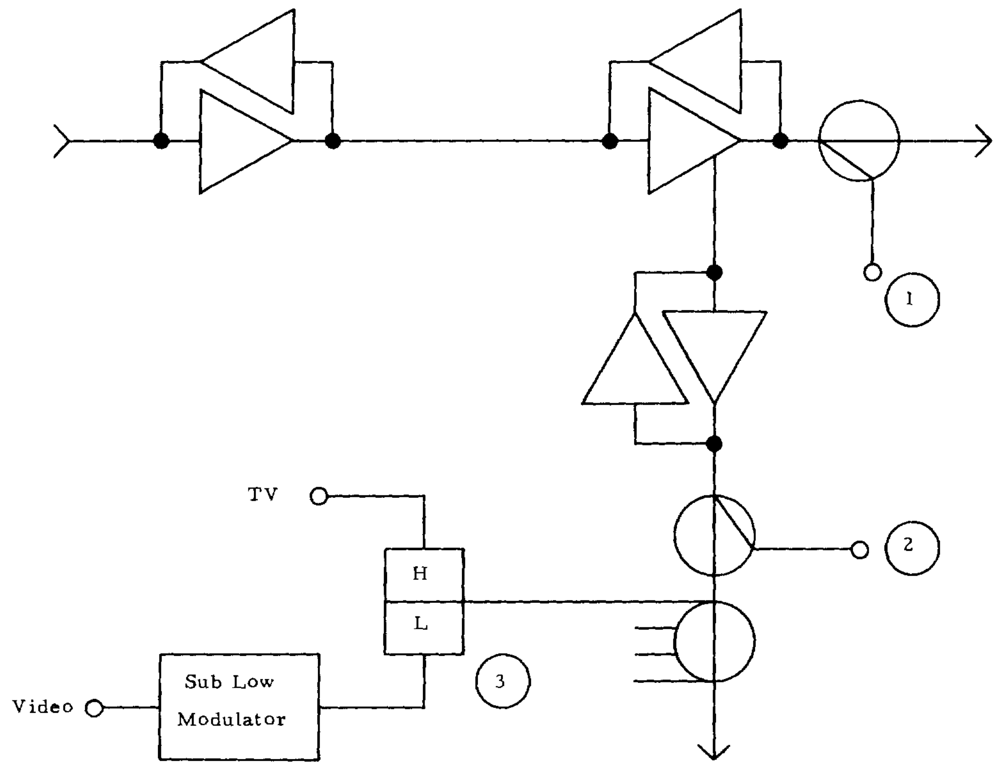


FIGURE 1 REVERSE SIGNAL INSERTION LOCATIONS

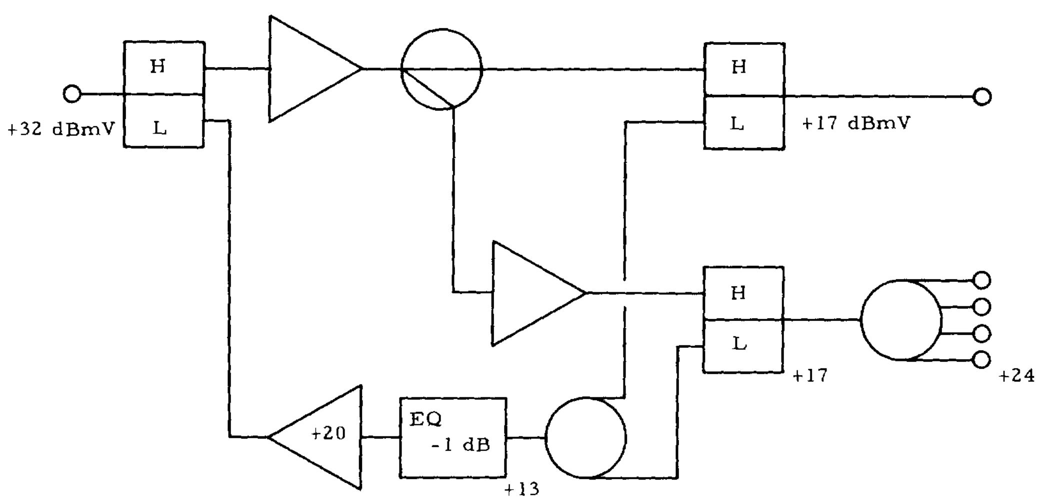


FIGURE 2 TYPICAL STATION LEVELS

system interruption occurs when the return signal is injected directly into a tap. Figure 1 shows three locations for inserting signals into the system.

Direct Trunk Insertion

Signals may be inserted into the trunk at either the first trunk reverse station or at any point in a reverse cascade. Usually if only one channel or one source location is used, the first reverse amplifier will be placed just ahead of that location. There would be no need for one placed further downstream. The first reverse module should be set for nearly maximum gain. It is common practice to leave one or two dB reserve gain for any unforseen level variations. Next, the required input level to the station must be calculated. Determine the actual operating gain and the desired output level. Desired output levels may usually be obtained from the manufacturer's data sheet. The output level minus the gain yields the input level to the amplifier module. Add to this level any combining losses, which may be built into stations, and the equalizer insertion loss, if not included in the amplifier gain. These losses mean that the input level to the station must be higher by that amount. Figure 2 shows an example of how these losses determine the input level.

The trunk directional coupler value must be determined next. To do this, the connecting cable losses and the signal source levels must be known. Calculate the cable losses at the actual reverse channel carrier frequencies, i.e., 13 MHz, 19 MHz, etc. If the signal source is a modulator, plan to operate it several dB below maximum output level to allow for level variations during actual set up and equipment aging. The directional coupler value can then be determined as the additional loss needed to meet the required input level after subtracting the cable loss from the modulator level. Typically, the coupler will be a DC-16 or DC-20. If the cable loss is relatively low, the modulator may be set near minimum output level or may even require pads to be placed at its output as shown in Figure 3.

Direct Distribution Insertion

The calculations of this method are very similar to that of the trunk insertion. The first reverse line extender module should be set just below maximum gain and the input level determined as before. Compute the cable and flat loss going into the trunk station by adding the cable loss at the carrier frequency and all distribution passives, taps, and combiner losses. Check the station block diagrams carefully for these losses. The combined cable and flat losses from the last (reverse direction) line extender to the trunk reverse module must be less than the trunk reverse amplifier gain. If it is not, the line extender reverse output level will have to be raised accordingly. Carry these levels back to the signal source to be sure that enough signal level is available. If additional level is required, use either a smaller direc-

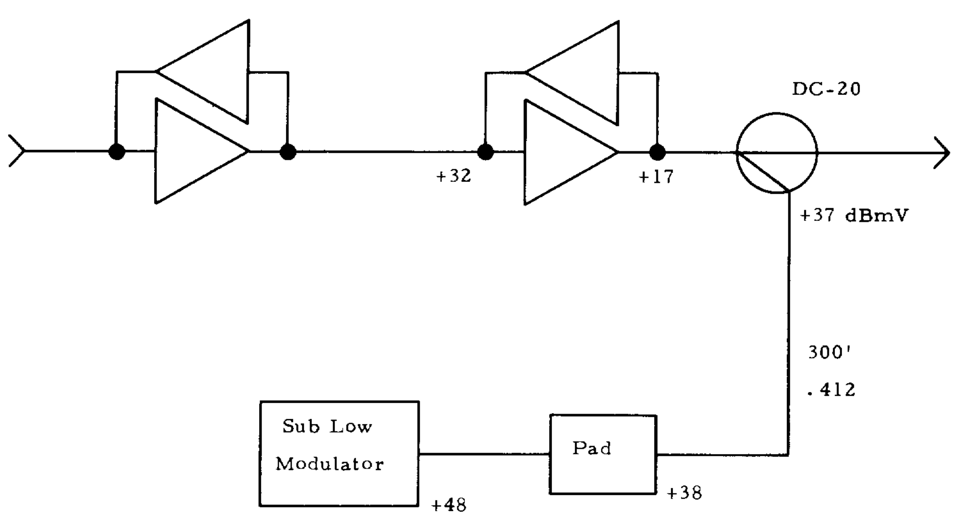


FIGURE 3 TYPICAL LEVELS FOR TRUNK INSERTION

tional coupler or additional amplification at the source. Figure 4 illustrates this method.

Directional Tap Insertion

The system calculations of this method are identical to that of the direct distribution insertion except that tap loss is considered instead of a directional coupler loss. All passives including taps must be able to pass the 5-30 MHz band. Many of the older taps and passives simply were not designed to operate at 5 MHz. Most systems which have been rebuilt or built recently will already have 5-300 MHz passives. If this is a special run where only a portion of the trunk was rebuilt for a specific reverse run, check the passives to assure they are also 5-300 MHz equipment. Replace any unit in the reverse system that does not pass 5 MHz with one that does. All modern passives that are designed to pass 5 MHz will have the same attenuation in both the forward and reverse direction. Figure 5 illustrates the tap insertion method.

System Balancing

The reverse system may be balanced in several ways:

1. Sweep
2. Meter Balance
   a) Two carrier reference
   b) One carrier-modulated

Sweep balancing is the cleanest and most accurate method. If several channels are planned or if a large part of the 5-30 MHz band is going to be used, the sweep method is certainly recommended. Connect the sweep generator at the source and set a reference as in normal forward sweep. Set sweep width for 5-30 MHz. Balancing is accomplished in the same way as in the forward direction, working from the source to the headend. The unity gain per span concept applies with this method as in the forward direction. If the reverse line extender output level must be different than the trunk output level because of more flat loss or cable loss, the sweep reference level will have to be shifted accordingly. A little thought and care will be necessary here. See Figure 6.

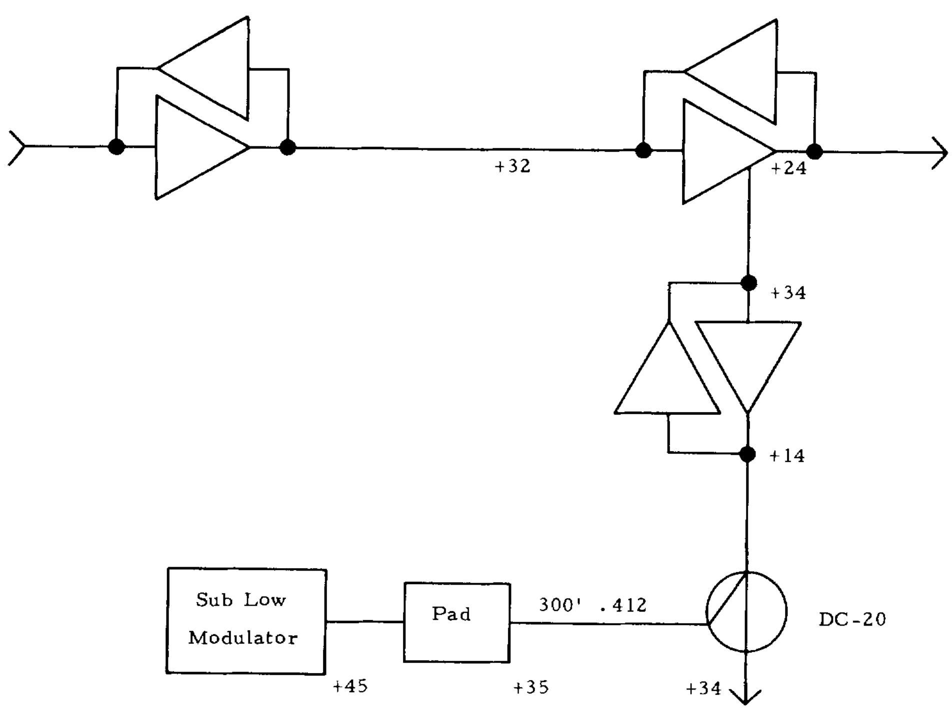


FIGURE 4 TYPICAL LEVEL FOR DISTRIBUTION INSERTION

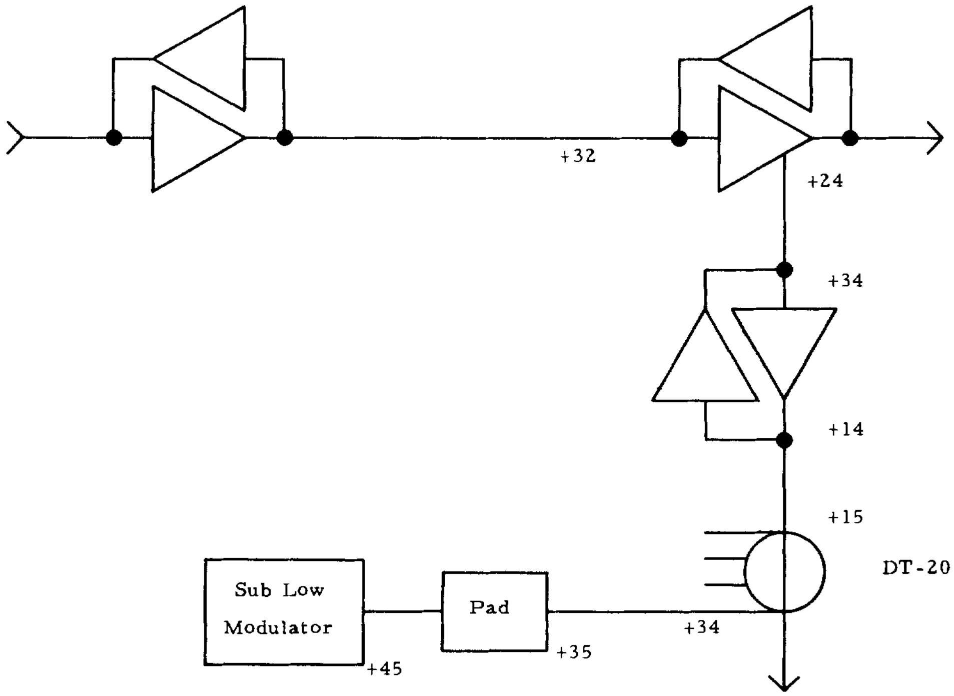


FIGURE 5 TYPICAL LEVELS FOR TAP INSERTION

Meter balancing is much easier but is less accurate. However, if two carriers are inserted so that one carrier frequency is near 30 MHz and the other is near 5 MHz, a reasonably close slope and gain condition can be achieved. A calibrated signal level meter should be used. Again, connect the signals at the source and balance upstream toward the headend. If the desired carrier is available, simply add a stable CW carrier as far away in frequency from it as possible and balance to these two. Balancing on one modulated carrier is possible, if the relationship between the video and sound carrier levels are closely maintained. This is not a desirable method due to the lack of adjustment resolution.

The actual mechanics of balancing will vary with the type of equipment used. The value of equalizers, the pivot point of the slope control if one exists, the type and location of test points, and recommended operating levels are different with each manufacturer.

Adding a Second Source

To add another source to a mid point location on a reverse system, determine the type of insertion method required, i.e., direct trunk or distribution insertion. Next, determine the input level necessary to make the new carrier compatible with the existing trunk reverse carrier. For trunk-inserted carriers, this could be taken at the input test point. For distribution sources, compatible levels would be taken at the trunk-distribution combiner as illustrated in Figure 2. Given the input levels, the remaining calculations are done as before.

Distortion Calculation

Cross-modulation calculations in cascade are made the same way as in the forward system but only for two or more channels. There can be no cross-modulation with only one channel. Any cross-modulation that does occur must be added directly to the contribution that channel will receive in the forward direction for a total cross-mod level. For example, if two reverse channels are used, compute the cross-mod for the reverse cascade based on two channels and add this to the cross-mod that each channel would normally receive in the forward direction.

To illustrate the accumulated cross-

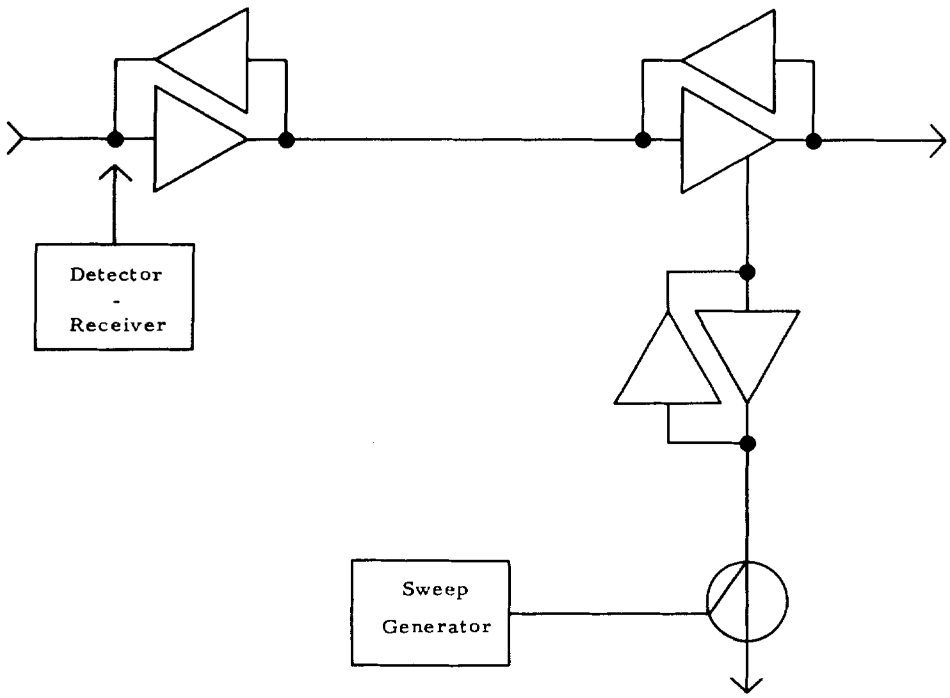


FIGURE 6 SWEEP EQUIPMENT SETUP

modulation of the reverse channels, assume that channel T9 goes through 10 reverse amplifiers, is converted to channel 6, and is sent down 20 forward amplifiers with 19 other forward channels. Assume further that channel T8 goes through 5 reverse amplifiers, is converted to channel 9, and is sent down the same forward cascade. No cross-mod would be generated in T9 from the tenth to the fifth station. Then, channels T8 and T9 would cause cross-modulation in each other through the five remaining reverse amplifiers. Compute the cross-mod of 2 channels through 5 amplifiers. A typical number might be:

-107 dB	for each amplifier
+ 14 dB	for five amplifiers
- 93 dB	for reverse system

The forward system of 20 channels and 20 amplifiers would contribute typically:

-93 dB	for each amplifier
+26 dB	for twenty amplifiers
-67 dB	for forward system on channels 6 and 9

The contribution of the reverse system to channels 6 (T9) and 9 (T8) is less than 1 dB, so the total system cross-mod on these two channels would be about -66 dB on the trunk.

Noise accumulation occurs in every amplifier location both forward and reverse. The total carrier-to-noise ratio is based on all amplifiers in the signal path. Since different types of amplifiers have different noise figures and different input levels, the base C/N of each station must be computed. These individual C/N are then added, through logrithms, to get a combined system C/N ratio.

To illustrate this concept, assume that channel T9 flows through 10 reverse stations and 20 forward stations. Assume C/N base numbers of -63 dB for the reverse and -59 dB for the forward stations.

-63 dB	for one reverse station
+10 dB	for ten reverse stations
-53 dB	for T9 in reverse

-59 dB	for one forward station
+13 dB	for twenty forward stations
-46 dB	for T9 forward

-53 dB reverse
-46 dB forward
-45 dB total

Carrier-to-noise ratio for T8 would be:

-63 dB for each reverse station
+ 7 dB for five reverse stations
-56 dB for reverse
-46 dB for forward
-45.6 dB total

Data Channels

Digital data channels such as computer links, telecommunications, or control links are handled somewhat differently from video channels. Typically, the bandwidth is from one to four megahertz and is a function of the data rate. Modulation type is usually a form of frequency shift keying (FSK) for control and computer links and pulse code modulation (PCM) for voice telecommunications. These data signals may then be applied to a high quality CATV type modulator for insertion into the cable system. Either AM or FM modulators will accept this type of modulation, but check with the manufacturer for proper operation. Some AM modulators have AGC circuits which operate from TV sync pulses and may be easily fooled by the lack of sync pulses in the data stream. FM modulators tend to have wider bandwidths than AM modulators, so carrier frequencies must be selected carefully to avoid interference.

Carrier-to-noise ratios are less critical on data carriers than on TV carriers. Data carriers are usually carried 10 dB below adjacent TV carriers to reduce any possibility of distortion to the TV carriers. If the reverse system is to carry data channels only and no video carriers, the data channel may be operated at normal system operating levels.

Conclusion

The two areas of consideration that must be carefully thought through is the calculation of signal levels at every stage in the cascade path and the unity gain balance points. Single channel systems are less critical of the actual operating level, but the trunk and distribution levels must be made compatible. Pay close attention to levels near the modulator to be sure that the modulator can supply sufficient level. Balancing techniques may have to allow for a difference in distribution and trunk return levels. This will be more difficult with sweep than with meter balancing. Good prior planning and forethought will prove invaluable.

COMPUTER-AIDED CATV SYSTEM DESIGN

Richard L. Amell

Cox Cable Communications, Inc.

ABSTRACT

Cox Cable Communications's Design and Drafting Department is equipped with four microcomputer systems to aid in the design of CATV systems. The computers perform all calculations involved in design of Bill of Materials, freeing the system designer to concentrate on routing, amplifier placement, and cost effectiveness. Computer-aided system design is faster, more accurate, and less costly than design produced with non-computer methods.

INTRODUCTION

In companies like Cox Cable that choose to develope large quantities of system design in-house, less than maximum production from the design staff can mean costly construction delays due to lack of maps and Bill of Materials.

A proficient designer, using a computer, can produce in excess of 15 miles of raw design (unpowered/no B.O.M.) in a normal work day. Non-computer-aided methods of design cannot compare in production speed.

Accuracy in system design is imperative. Designing with a simple calculator requires repeated entry of data such as input and output levels, cable losses, and insertion losses. Minimizing the number of keyboard entries will reduce the possibility of keyboard entry errors. Computer-aided system design requires a minimum of keyboard entries. A computer, using custom programming, will instantly calculate all losses and new levels as each span measurement or device selection is entered.

HARDWARE

Cox Cable Communications, Inc. (CCCI) has chosen Wang Laboratories Model 2200 computers for use in system design. While other computer manufacturer's equipment can duplicate most if not all the features incorporated in the Wang 2200 systems, Wang offers excellent dependability at a comparatively low price.

CCCI currently uses four 2200 systems in the Design Department. All four systems are multiplexed to a dual diskette drive and a 120 character per second 7x9 dot matrix printer.

The dual diskette drive provides 524, 288 bytes of off line storage of programs and data. Disk based storage is preferred to cassette tape based storage. Disk systems have a much faster transfer rate than cassette tape systems, and disk provides direct access to stored data. In contrast, data is stored and loaded sequentially on cassette tape systems.

The Wang 2200 series of computers are 8-bit word length machines. The language (BASIC) and its compiler are stored in ROM (42.5K). Storage and transfer code is ASCII.

Each CCCI computer is equipped with 16K (16,384 bytes) of Random Access Memory (RAM). Seven hundred bytes of RAM are required to interface RAM and ROM, leaving 15,686 bytes of user-available RAM.

CCCI's Wang computers are equipped with several features that have proven to be invaluable both in the writing of programs and in actual design.

<u>16 User Defined Special Function Keys</u>. The 16 Special Function keys allow single key stroke access to any of 32 custom subroutines. All active and passive CATV devices are selected using one of the Special Function keys for both Design and Bill of Materials.

<u>Separate Numeric Keypad</u>. All four CCCI computer keyboards are equipped with calculator format numeric keypads. This simplifies entry of numeric data (such as span footages) and minimizes entry errors.

<u>Programmable Audio Signal</u>. A 960 Mz beep tone may be program-activated on all four computers. This beep tone serves as an alarm to alert a designer that an entry error has been made or some pre-assigned design parameter has been exceeded.

Edit Capability. Computers that are not equipped with edit functions force a programmer to re-enter an entire line of program text if an error is made while entering the line. With edit capability, the programmer is only required to correct the specific error.

The Wang 2200 system's program language is BASIC (Beginner's All Purpose Symbolic Instruction Code). BASIC is the most common higher level computer language which uses many close-to-English key words. It is the simplest of all computer languages to learn.

SOFTWARE

An effective computer-aided CATV design program must meet the following criteria:

1. All cable losses, insertion losses, and operating levels must be stored in memory and accessed under program control.

2. A single program must function for design of both trunk and feeder.

3. Operation of the program should be simple enough that a person not familiar with computer hardware or computer programming can nonetheless be an effective CATV system designer.

4. Bill of Materials should be compiled in a step after completion of raw design. Attempting to compile Bill of Materials as a part of the design process only serves to slow the designer and lessen the accuracy of the completed Bill of Materials. If necessary, a designer must be able to go back over previously completed work and make changes without concern for previously "SAVED" materials.

5. The computer should function as a "TOOL" for the designer. Decisions regarding placement of amplifiers and cable routing are still best left to the human designer.

DESIGN

Figure 1 is a simplified flow chart for CCCI's CATV design program. To conserve memory, the design program is actually two programs chained together.

Program "DES-1" assigns the following design parameters to the proper array variables for subsequent use in the primary design program ("DES-2"):

1. All cable losses for both high and low design frequencies. (1.000 in. Trunk, .750 in. Trunk, .500 in. Feeder, and .412 in. Feeder)

2. All operating levels for both Trunk and Feeder amplifiers.

3. All directional tap values and insertion losses.

4. All passive device losses.

The designer is given the option of changing any or all levels or losses to meet different job requirements. (In practice all major system designs have a disk dedicated for that system's levels and losses.) If no changes are desired, the computer will load program "DES-2" over "DES-1". All variables assigned in program "DES-1" remain in memory for use in "DES-2".

No attempt is made to compile Bill of Materials while designing for reason previously mentioned. Compiling the Bill of Materials is the final step in the design process.

All active and passive devices are selected with a user defined Special Function Key. The Special Function Keys access subroutines (smaller programs within a larger program) which assign the selected active device output levels or subtract the selected passive device insertion losses.

The designer is free to move from Feeder to Trunk or from Trunk to Feeder at will. The numbers 1, 2, 3, 4, and 5 are used by the program as code numbers. By entering the proper number, the designer may select Bridger outputs (1, 2, 3, or 4) or Trunk output (5).

The design program is written to be interactive. The designer enters strand footages or selects devices in response to CRT-displayed prompts.

Note: All references within the design program flow chart (Figure 1) to "Print" are CRT displays.

BILL OF MATERIALS

The Bill of Materials for completed design is compiled as a final step in the design process using the programs shown in the simplified flow charts in Figures 2 and 3.

The Compiling Program (Figure 2) is used to total all cable, passive devices, active devices, and connectors for a single map or power supply.

The numbers 1, 2, 3, or 4 are used as code numbers by the program, allowing the Bill of Materials Clerk to change cable sizes at will. (1 for 1.000 Trunk, 2 for .750 Trunk, 3 for .500 Feeder, and 4 for .412 Feeder.)

All active and passive devices are counted with a single key stroke using the proper user-defined Special Function Key.

Connectors are counted automatically under program control. Connector size is determined by the selected cable size. Connector quantity is equal to the number of connectors required for the selected device.

When all devices and cable for the map or power supply have been entered, the Bill of Materials Clerk will obtain a printout of the totals.

The Printout Programs (Figure 3) are loaded under program control. The Individual Map Printout program section provides the printout for the material counted with the Compiling Program. Figure 4 is a sample printout of a single map or power supply.

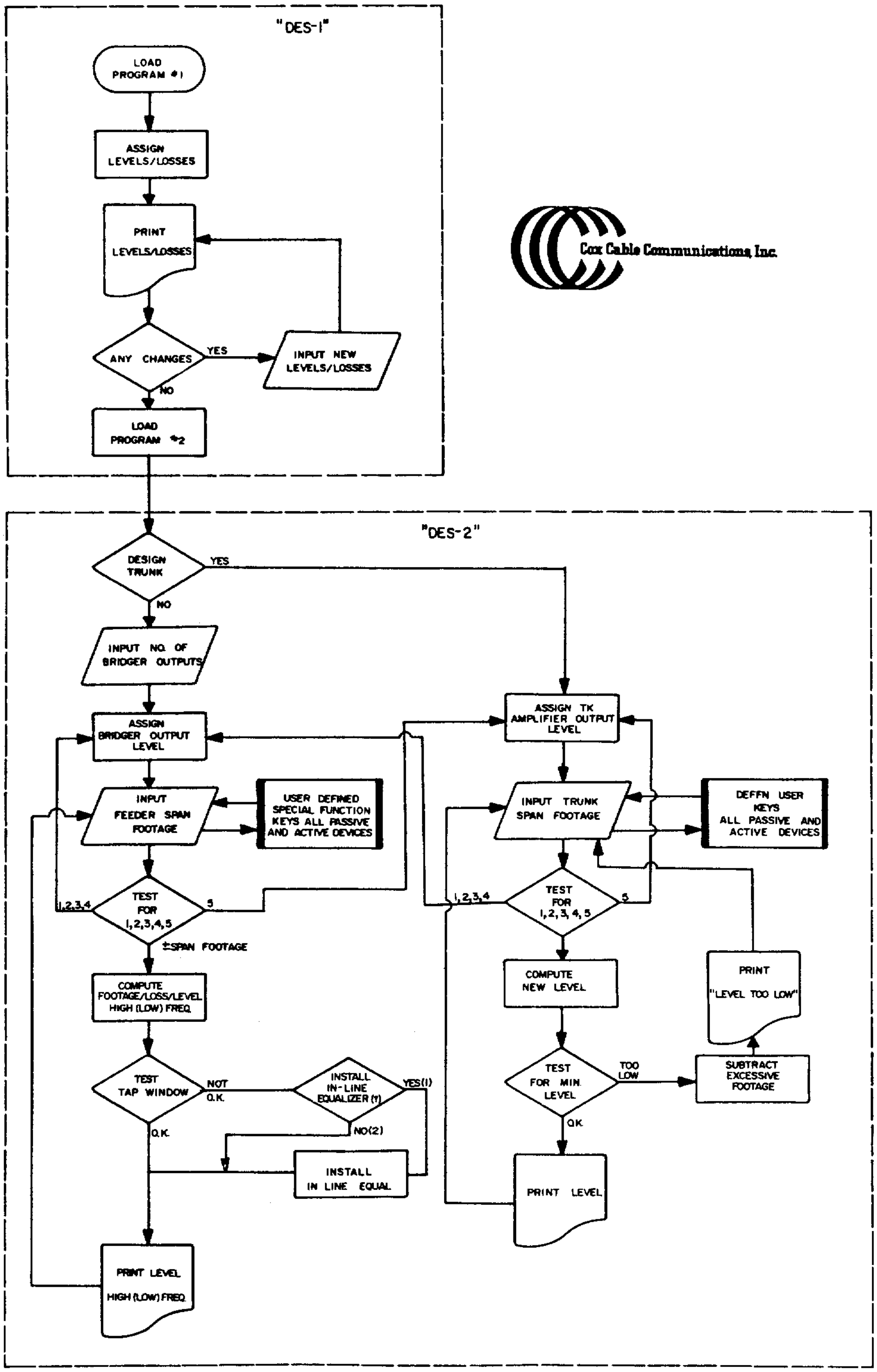
When the printout of the single map or power supply totals is completed, the totals are added to the cumulative total stored off line on disk. The updated cumulative totals are resaved on the disk and the Cumulative B.O.M. Printout program is loaded.

The Cumulative B.O.M. Printout program will print out an updated total of all material counted. This printout also includes the cost of each item, the extended costs, and total per mile costs for Cable, *Directional Taps*, and Electronics. Figure 5 is a sample Cumulative Bill of Materials printout.

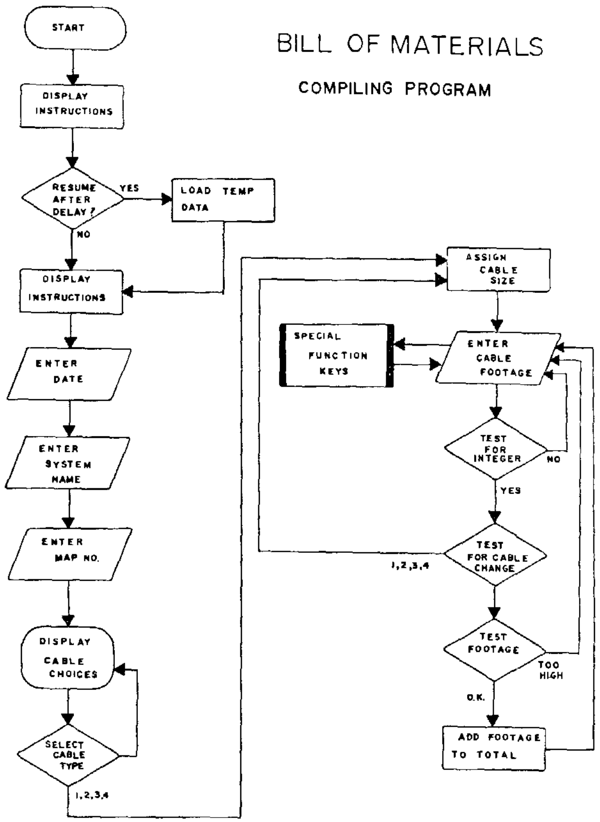
SUMMARY

Using computer-aided methods, Cox Cable Communications, Inc. continues to develop all new system design in-house. The overall cost savings is significant, however equally important is the control over production obtained by not relying on outside sources for system design.

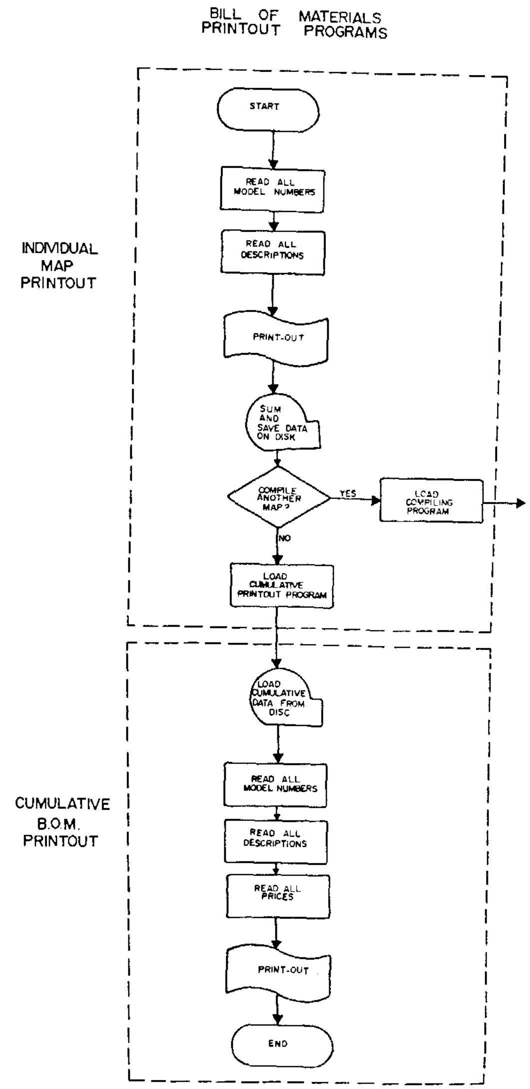
Cox Cable Communications, Inc.



CATV DESIGN PROGRAM
WANG 2200
FIGURE 1



(Figure 2)



(Figure 3)

((RLA))

COX CABLE COMMUNICATIONS INC.

BILL OF MATERIALS

ANYTOWN, USA 3/27/79 MAP NO OR POWER SUPPLY

ACTIVE DEVICES / ASSOCIATED EQUIPMENT

MODEL	DESCRIPTION	QTY	MODEL	DESCRIPTION	QTY
5-2-TC1BR	TK/BR - AGC/ASC	0	5-2-E300-0	TK EQUALIZER	0
5-2-TBR	TK/BR - MAN	0	5-2-E300-5	TK EQUALIZER	0
5-2-TC1R	TK - AGC/ASC	0	5-2-E300-8	TK EQUALIZER	0
5-2-TR	TK - MAN	0	5-2-E300-11	TK EQUALIZER	0
5-2-DBR	INT/TERM BR	0	5-2-E300-14	TK EQUALIZER	0
			5-2-E300-17	TK EQUALIZER	0
			5-2-E300-20	TK EQUALIZER	0
5-S1	FEEDER MAKER	0			
5-S2	FEEDER MAKER	0	5-EE300-0	L.E. EQUALIZER	0
5-S3	FEEDER MAKER	0	5-EE300-5	L.E. EQUALIZER	0
5-S4	FEEDER MAKER	0	5-EE300-8	L.E. EQUALIZER	0
			5-EE300-11	L.E. EQUALIZER	0
			5-EE300-14	L.E. EQUALIZER	0
			5-EE300-17	L.E. EQUALIZER	0
5-LE/34	LINE EXTENDER	0	5-EE300-20	L.E. EQUALIZER	0

DIRECTIONAL TAPS

MODEL	QTY	MODEL	QTY	MODEL	QTY
3732/2	0	3735/4	0		
3729/2	0	3732/4	0		
3726/2	0	3729/4	0	3833/8	0
3723/2	0	3726/4	0	3830/8	0
3720/2	0	3723/4	0	3827/8	0
3717/2	0	3720/4	0	3824/8	0
3714/2	0	3717/4	0	3821/8	0
3711/2	0	3714/4	0	3818/8	0
3708/2	0	3711/4	0	3815/8	0
3704/2	0	3708/4	0	3811-T/8	0
TOTAL 2'S	0	TOTAL 4'S	0	TOTAL 8'S	0
TOTAL TAPS	0			EMI-500(FT)	0
TAPS/MILE				EMI-412(FT)	0

PASSIVES, CABLE, CONNECTORS

MODEL	DESCRIPTION	QTY	MODEL	DESCRIPTION	QTY
			1.000	P-III CABLE	0
4-TFC-3	2-WAY SPLITTER	0	.750	P-III CABLE	0
4-TFC-8	DIR COUPLER	0	.500	P-III CABLE	0
4-TFC-12	DIR COUPLER	0	.412	P-III CABLE	0
4-TFC-377	3-WAY SPLITTER	0	EFI-1000	CONN	0
FFE-8	IN-LINE EQUAL.	0	EFI-750	CONN.	0
625-TRB	TERMINATOR	0	EMI-500	CONN. (NFT)	0
ETE-625R	ADAPTER	0	EMI-412	CONN. (NFT)	0

STRAND MILES	0	FD/TK RATIO	LE/MILE
DIST MILES	0		TK AMPS/MILE
TRUNK MILES	0		ACTIVES/MILE

(Figure 4)

((RLA))

ANYTOWN, USA

BILL OF MATERIALS/COST SHEET

MILES- 0

COX CABLE COMMUNICATIONS INC. 3/27/79

TAP	QTY	UNIT COST	EXT COST
3732/2	0	0	0
3729/2	0	0	0
3726/2	0	0	0
3723/2	0	0	0
3720/2	0	0	0
3717/2	0	0	0
3714/2	0	0	0
3711/2	0	0	0
3708/2	0	0	0
3704/2	0	0	0
TOTAL FFT-2'S- 0			
3735/4	0	0	0
3732/4	0	0	0
3729/4	0	0	0
3726/4	0	0	0
3723/4	0	0	0
3720/4	0	0	0
3717/4	0	0	0
3714/4	0	0	0
3711/4	0	0	0
3708/4	0	0	0
TOTAL FFT-4'S- 0			
3836/8	0	0	0
3833/9	0	0	0
3830/8	0	0	0
3827/8	0	0	0
3824/8	0	0	0
3821/8	0	0	0
3818/8	0	0	0
3815/8	0	0	0
TOTAL FFT-8'S- 0			
TOTAL TAPS- 0			
TAPS/MILE -			

MODEL	DESCRIPTION	QTY	UNIT COST	EXT COST
5-2-TC1BR	TK/BR-AGC/ASC	0	0	0
5-2-TBR	TK/BR-MAN	0	0	0
5-2-TC1R	TK-AGC/ASC	0	0	0
5-2-TR	TK-MAN	0	0	0
5-2-DBR	INT/TERM BR	0	0	0
5-2-E300-0	TK EQUALIZER	0	0	0
5-2-E300-5	TK EQUALIZER	0	0	0
5-2-E300-8	TK EQUALIZER	0	0	0
5-2-E300-11	TK EQUALIZER	0	0	0
5-2-E300-14	TK EQUALIZER	0	0	0
5-2-E300-17	TK EQUALIZER	0	0	0
5-2-E300-20	TK EQUALIZER	0	0	0
5-S1	FEEDER MAKER	0	0	0
5-S2	FEEDER MAKER	0	0	0
5-S3	FEEDER MAKER	0	0	0
5-S4	FEEDER MAKER	0	0	0
5-LE/34	LINE EXTENDER	0	0	0
5-EE300-0	L.E. EQUALIZER	0	0	0
5-EE300-5	L.E. EQUALIZER	0	0	0
5-EE300-8	L.E. EQUALIZER	0	0	0
5-EE300-11	L.E. EQUALIZER	0	0	0
5-EE300-14	L.E. EQUALIZER	0	0	0
5-EE300-17	L.E. EQUALIZER	0	0	0
5-EE300-20	L.E.EQUALIZER	0	0	0
4-TFC-3	2-WAY SPLITTER	0	0	0
4-TFC-8	DIR COUPLER	0	0	0
4-TFC-12	DIR COUPLER	0	0	0
4-TFC-377	3-WAY SPLITTER	0	0	0
1.000	P-III CABLE	0	0	0
.750	P-III CABLE	0	0	0
.500	P-III CABLE	0	0	0
.412	P-III CABLE	0	0	0
EFI-1.000	CONNECTOR	0	0	0
EFI-750	CONNECTOR	0	0	0
EMI-500	CONNECTOR	0	0	0
EMI-412	CONNECTOR	0	0	0
EMI-500	CONN. (F/T)	0	0	0
EMI-412	CONN. (F/T)	0	0	0
ETE-625R	ADAPTER	0	0	0
625-TRB	TERMINATOR	0	0	0
FFE-8	IN-LINE EQUAL.	0	0	0
	POWER SUPPLY	0	0	0
4-LPI	POWER COMBINER	0	0	0

TK AMPS PER MILE-	STRAND MILES- 0	TAPS COST/MILE- 0
LE'S PER MILE-		
ACTIVES PER MILE-	TRUNK MILES- 0	CABLE COST/MILE-
FD/TK RATIO-	FEEDER MILES- 0	ELECTRONICS COST/MILE-

(Figure 5)

DESIGN OF FIBER OPTIC BASEBAND VIDEO SYSTEMS

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ABSTRACT

Design of fiber optic single channel video systems is discussed. Attainable unrepeatered system length, and system performance are given. A discussion of source and detector selection, receiver sensitivity, fiber bandwidth, and the effect of nonlinear distortions are presented.

INTRODUCTION

Considerable effort has gone into the design of various fiber optic digital systems; consequently, the technology as it applies to that field is well understood[1]. The application of optical fiber to the transmission of analog signals has been less intensive, mainly because of technical limitations and lower demand. Nevertheless, fiber optics is beginning to make inroads into the analog market[2] although on a lower scale.

The following is a discussion of the basic system design considerations for an application requiring the transmission of baseband video signal over a fiber optic cable.

SYSTEM DESCRIPTION

A fiber optic video transmission system is functionally similar to other cable systems - it consists of a line driver(transmitter), cable, and a line receiver. However, the way in which these components are implemented in fiber optic systems differs drastically from conventional cable systems.

The transmission medium is completely dielectric, and therefore, does not conduct electric currents. The information is carried through the cable via the intensity modulated light beam. Consequently, the function of the line driver and that of a line receiver is to interface between the electrical medium and the optical fiber. A block diagram of a fiberoptic transmission system is shown in Fig. 1.

At the transmitter end, a composite video signal from a camera or a VTR is fed through a 75Ω coaxial patch cable to a voltage to current converter. The resulting current drives either a Light Emitting Diode(LED) or an Injection Laser Diode (ILD) which generates a light signal with intensity proportional to the voltage of the composite video signal. This intensity modulated light is coupled into a fiber pigtail which guides the light into the optical cable. The transmitter is connected to the cable via a demountable fiber optic connector. The light, once in the cable, travels within the glass fiber where it undergoes attenuation and band limiting.

At the receiver end of the system, a photodetector converts the light signal into electrical current which in turn is amplified and processed to give a composite video signal identical to the signal at the output of the video camera. As a result of the processing performed at the receiver, the fiber optic system appears transparent to the electrical signal, and in a properly designed system, minimally degrades the video quality.

The maximum distance over which a video signal can be transmitted depends on the available transmitter power, receiver sensitivity, and the cable loss per unit length. The distance(in km) is given by equation 1:

$$L = \frac{P_T - 2A_C - P_R}{A} \qquad (1)$$

Where P_T is the optical power coupled into the fiber by the transmitter(in dBm), A_C is the attenuation(in dB) of a single optical connector, P_R is the minimum light power(in dBm) required to obtain a specified signal to noise ratio, and finally, A is the attenuation of the fiber optic cable per unit length(in dB/km). The individual system parameters are determined by the choice of components and the design of electronic circuitry.

SYSTEM COMPONENTS

Transmitter

The critical design consideration for a transmitter is the selection of a light source. Ideally, in order to assure maximum transmission length, a source that yields maximum undistorted light signal is selected. In practice, however, the system cost and its reliability must also be considered. Three types of light emitting devices are currently used in fiber optic communications - a Light Emitting Diode(LED), a multimode Injection Laser Diode(ILD), and a single mode ILD. Typical parameters characterizing these devices are listed in Table I.

Table I

	LED	ILD multi-mode	ILD single mode
Light power coupled into a 5 mil fiber	-16 to -10 dBm	0 to +10 dBm	0 to +10 dBm
2nd harmonic at 75% modulation	-35 dB	-15 to -30 dB	-50 to -60 dB
3rd harmonic at 75% modulation	-45 dB	---	< -60 dB
Wavelength	840 nm	840 nm	840 nm
Spectral width	40 nm	2 nm	< 2 nm
Projected useful life	10 years	1-2 months	1-10 years
Transmitter complexity	Low	High	High
Price, small quantities	$100.- $350.	$500.- $1000.	$2,500.- $3,500.

It can be seen that the multimode laser diode is not a good choice for application in an analog intensity modulated system primarily because of its short life time and very high distortion levels. The single mode laser diode is a better choice from the performance point of view, however, its high price and lack of adequate data on its reliability make this device an unattractive choice at the present time. The LED on the other hand is inexpensive, reliable, and has adequate performance for most applications of a baseband system.

A typical light vs. current curve for an LED is shown in Fig. 2. The light output power P_T can be expressed as a sum of current harmonics, as shown below.

$$P_T = a_1 I + a_2 I^2 + a_3 I^2 + \dots \qquad (2)$$

The coefficients a_1, a_2, and a_3 are current dependent[3], and correspond to the fundamental, second and third harmonics respectively. It can be shown that for a standard staircase input, the color subcarrier compression or the differential gain can be approximated by the following expression:

$$\text{Diff Gain}(\%) = \left(\frac{1+3.6\ a_2 + 10a_3}{1-2.2a_2 + 3.7a_3} - 1\right) \times 100\% \qquad (3)$$

Using the values for 2nd and 3rd harmonic listed in Table I, the differential gain is calculated to be 14% at 75% modulation. If the modulation index is decreased to 50%, the 2nd and 3rd harmonics drop to approximately -38 and -50 dB respectively[3] yielding a differential gain of 9% which is an acceptable level in a large number of applications.

The differential phase is more difficult to calculate. Experimental results show it to be less than 3° in most devices.

Cable and Connectors

Both the cable and connectors introduce loss into the system. The connector losses stem from fiber misalignments and variations in parameters between the two fibers being joined. Commercially available connectors exhibit losses that range anywhere between 0.5 dB and 2 dB.

The fiber exhibits two types of losses. One similar to the ohmic loss in the coaxial cable is caused by light scattering and absorbtion in the glass medium. This loss is uniform over the entire fiber bandwidth, and ranges between 4 and 5 dB/km for currently available fiber cables. The other type of fiber loss is frequency dependent and, as in coaxial cable, limits the useful bandwidth. The bandwidth depends on the light source used, and for ILD's a typical fiber will exhibit a 3 dB bandwidth of 300-400 MHz over the distance of 1 km. When an LED is used as a source, the available bandwidth is considerably lower. An approximate experimentally determined relationship between fiber bandwidth F and its length L is given below.

$$F = 45\ \text{MHz}/L(\text{km}) \qquad (4)$$

Therefore, a 2 mile long fiber cable will have a 3 dB bandwidth of 14 MHz, which is more than necessary to transmit a baseband video signal.

Receiver

The primary objective in designing a receiver circuit is to maximize the signal to noise ratio at the output of the transmission system. This objective is achieved by first maximizing the power transferred between the photodetector and the preamplifier and, second, by minimizing the noise power introduced by the preamplifier circuit.

The photodetector appears as a nearly ideal current source; therefore maximum power transfer is achieved with a high impedance preamplifier circuit[4]. In order to maximize the power transfer over the entire frequency range of interest, a circuit with high input resistance and low input capacitance must be used. In order to minimize noise power introduced by the preamplifier, current noise sources must be minimized. This implies that transistors with low input bias currents and high internal gains must be employed.

A preamplifier design utilizing a Field Effect Transistor(FET) as a first gain stage satisfies all of the above requirements[5]. It is well known[6] that the equivalent noise current, that is, the current that would have to be present at the input to the preamplifier to produce the measured noise voltage at the output, can be written as the following integral:

$$I_n^2 = \int_o^B \left(2qI_BM + \frac{4kT}{RiG^2} + \frac{4kT}{gG^2} C_i^2 \omega^2\right) df \qquad (5)$$

Where B is the receiver bandwidth, q - electron charge, I_B - average photocurrent, M - detector noise factor, k - Boltzman constant, T - temperature in °K, g - FET transconductance, G - photodetector internal gain, C_i - input capacitance of the preamplifier, ω - frequency in radians. The first term represents the shot noise generated by the photodetector. The second term represents the effective thermal noise of the input resistors. Here, the effect of high input resistance is seen. The higher the resistance, the lower the effect of thermal noise. Finally, the last term represents the effective noise caused by the presence of input capacitance. The smaller the input capacitance, the lower the signal loss at higher frequencies, and therefore, the lower the effect of transistor noise. The signal to noise ratio is simply the ratio of peak signal photocurrent squared(I_s^2) to I_n^2.

Two types of photodetectors are used in fiber optic receivers - a PIN diode for which M=G=1 and an Avalanche Photodiode (APD) which exhibits internal gain G and whose noise factor M is gain dependent[7]. In systems employing APD's, the gain G is adjusted to minimize I_n^2. This effectively puts the receiver noise into the shot noise region, i.e., the first term in equation 5 is made dominant. In baseband video systems however, where the required signal to noise ratio is high, the average photocurrent level I_B is such that even with G=1 and M=1, the first term is dominant. For example, in order to attain a signal to noise ratio of 50 dB in a typical receiver(Ck=10pF, R_i=300 kΩ, g=4 mhos, B=4.5 MHz), in a system where $I_s=0.5I_B$, the required average current is 1μA. Substituting these parameters into equation 5 one finds that the first noise term is three times the sum of the other two terms. Therefore, it is easy to see that for systems requiring the signal to noise ratio in the vicinity of 50 dB, both the PIN and APD diodes have similar performance since both keep the receiver noise in the shot noise limit. Since PIN is considerably easier to use, most designs employ PIN photodetectors. Using the typical receiver parameters listed above and the PIN light to current conversion constant of 0.5 Amp/Watt, the sensitivity of the receiver, that is, the light power required to produce a signal to noise ratio of 50 dB, can be determined. For a 50% carrier modulation, the average received power should be 2μW(-27 dBm).

SUMMARY

Using Equation 1 and typical system parameters given in previous sections, i.e. P_R = -27 dBm, a maximum unrepeatered system length can be calculated. This length for a system exhibiting an unweighted signal to noise ratio of 50 dB in 4.5 MHz bandwidth and differential gain less than 10% is 2.8 km. If the single mode laser is used in the transmitter circuit, the system length can be extended by an additional 3-4 km.

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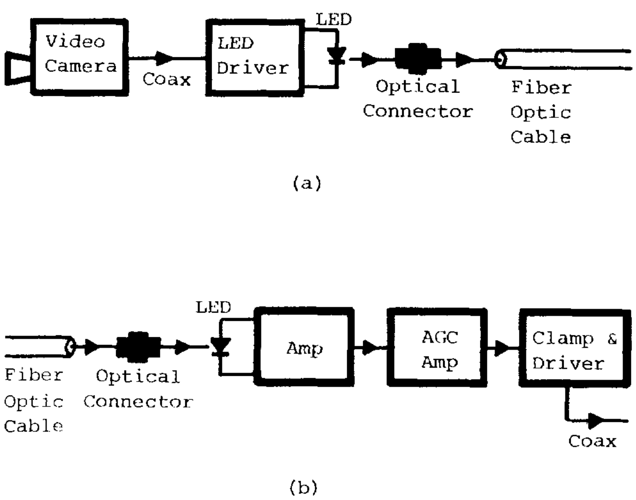

Fig. 1. Block diagram of a fiber optic video transmission system. (a) Transmitter end. (b) Receiver end.

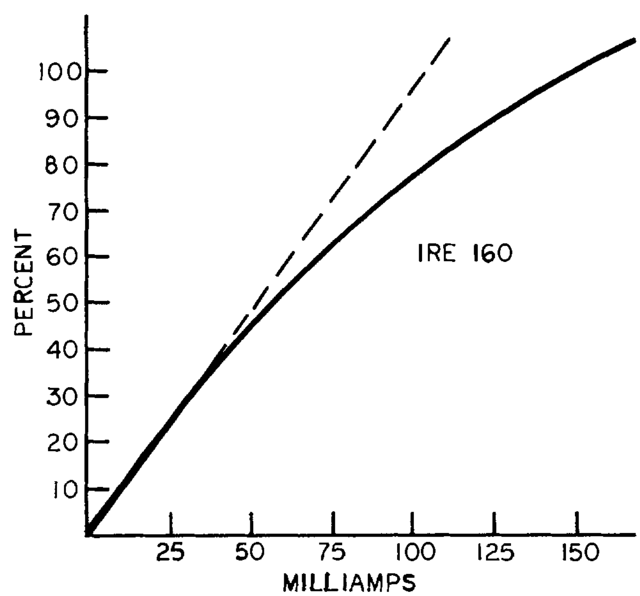

Fig. 2. Measured diode efficiency as a function of drive current.

DEVELOPMENT OF A CATV TECHNICAL PRACTICES MANUAL

Michael McKeown

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Atlanta, Georgia

ABSTRACT

A Technical Practices Manual as described in this paper can be considered a company operations manual for the technical personnel in a cable television (CATV) system. As a fast growing multiple system operator (MSO) Cox Cable saw a need to document and codify its technical practices to provide new systems with proven operational standards and procedures and help insure that its geographically widely spread existing systems met uniformly high operating standards. Included in this paper are the concepts involved in producing such a document and limited excerpts from the Technical Practices Manual which resulted from this work.

INTRODUCTION

It is the objective of this paper to document the need for a Technical Practices Manual in CATV operation and provide information on how to produce such a manual. This will be done by tracing the steps involved in producing the Cox Cable Communications (CCC) Technical Practices Manual on a "case history" basis. This "case history" will start with an examination of the need for a manual and a subjective cost vs. benefit analysis. The planning, acquisition of input, organization, and mechanical preparation are covered next. Finally, conclusions regarding the work already completed and suggestions for future work and other possible uses of the manual are dealt with.

THE NEED

A Technical Practices Manual is fundamentally an organizational guideline which sets forth broad company policy and prescribed procedures in the technical area of CATV operations. As an administrative guide it can serve to inform all technical personnel of the philosophy and business concepts of top management. For CCC the decision to produce a Technical Practices Manual came because of several anticipated reasons: 1)accelerated growth, 2) an increased number of employees requiring training, 3) new systems being turned on, 4) a desire to provide greater continuity to the company's operation should key technical personnel leave or become unavailable.

A Technical Practices or Operations Manual is probably needed if any of the four areas above apply to an organization.

A successful Technical Practices Manual can help a cable operator:

* ensure continuity despite changes in personnel or management
* create more efficient operation procedures
* create a valuable technical training tool
* define goals and ways to achieve them
* relieve technical management from the constant press and involvement in details
* improve intercompany communications
* provide better employee relations

As a training tool the manual is invaluable to introduce new employees to the companies' policies and practices. A more efficient organizational structure can result from the creation and use of a Technical Practices Manual since people who better understand what they are to do and how to do it tend to do it better. How often have we heard the lament of the employee who says, "I did not know what you wanted me to do." Further, it can help people view their position in terms of long-range rather than short-range goals.

Expansion is simplified when existing procedures are documented in an operations manual and new policy and practices can be more easily incorporated in a set of guidelines already established and well known in the organization.

PLANNING

Once the decision is made to produce a manual an individual or department must be charged with the task. Before beginning, careful planning and scheduling of the project should take place. The best choice of a person to handle the job is a technically competent individual with a broad perspective of the technical operation and the ability to express himself well in writing. Lacking that combination of talents in one person, it is best to team a good writer with an engineer. As a first step in planning, objectives must be set. The reasons for having a manual, previously discussed, can become a foundation for the objectives of a Technical Practices Manual. At this point it is useful to jump ahead a bit and use an excerpt from the INTRODUCTION section of the Technical Practices Manual.

SECTION 1
January, 1979

TECHNICAL PRACTICES

INTRODUCTION

The construction and operation of a cable television (CATV) system requires the coordinated contributions of many talented people. A typical CATV system has a system manager managing and developing people involved in office, sales, engineering, installation, and construction activities. Their mission or continuing purpose in operating the system is:

To provide cable television service to an ever-increasing number of satisfied customers at a profit sufficient to assure the growth, improvement, and continuity of the company and the people in it, and to contribute to the community in which they operate.

The purpose of this Cox Cable Communications (CCC) Technical Practices Manual is to aid engineering, installation and construction personnel in accomplishing the mission stated above. The key areas in which technical personnel can produce results which help accomplish the mission are:

1. Improved customer service by improving the reliability and quality of the service.
2. Increased professionalism of technical personnel.
3. Lowered operating expenses.
4. Increased useful life of company property.

The technical practices contained in this manual serve as a basic reference text in the technical operations of a CATV system. Cox Cable systems range in size from under 1,000 to over 165,000 subscribers. Since each system and the community it serves is unique no written document could hope to cover every situation. This manual was conceptualized as a set of guidelines and a training reference rather than a hard and fast set of rules. It is not intended to be a substitute for common sense and individual initiative and judgment.

This manual contains no secrets and while its distribution has been limited to Cox Cable technical management personnel, its use and readership can and should include all CCC technical personnel. When wider distribution is required it is suggested that the relevant section or sections be duplicated and posted or given to each individual. No part of this manual should be "borrowed" or permanently removed.

Your suggestions regarding errors or suggestions for improvements are welcome and encouraged. Refer to Practice 4 "Suggestion/Complaint Report Form" and address your comments to the Vice President-Engineering, Cox Cable Communications, Atlanta, and your Division Engineer.

(END OF SECTION 1 EXCERPT)

With the objectives clearly set it is useful to prepare an outline of the general topic areas to be covered. This organization step is important since it is the skeleton of the manual to which the "meat" will be added later to make it complete. It will also greatly affect the ease with which the finished product can be used. Initially the general topic areas included DESIGN/STANDARDS, EQUIPMENT REPAIR, PREVENTIVE MAINTENANCE, and others with individual sections of technical practices such as Earth Station, Microwave, Headend, Studio and Distribution System in each general topic area. This approach was later abandoned for one where general topic areas included EARTH STATION, MICROWAVE, HEADEND and DISTRIBUTION SYSTEM with individual sections in each covering subjects like Design Standards, Corrective Maintenance, and Preventive Maintenance. It was felt that this makes the use of the manual easier and more closely parallels the job functions in a medium or large cable system where one person is more likely to be involved in many aspects of the distribution system than he is working on preventive maintenance for earth station, microwave, headend and distribution equipment. In a smaller system where one individual may, indeed, perform preventive maintenance on all parts of the system the final structure of the manual still proves useful since he/she can find all material dealing with a particular location, i.e., earth station or studio under one general topic area of the manual.

The general topic areas are:

- FORWARD
- CONSTRUCTION
- CUSTOMER SERVICE
- DISASTER PLAN
- DISTRIBUTION SYSTEM
- EARTH STATION
- HEADEND
- INSTALLATION
- MICROWAVE
- REGULATORY
- SAFETY
- STUDIO
- SUBSCRIBER TERMINALS
- TEST EQUIPMENT
- TRAINING
- TWO-WAY RADIO
- VEHICLES
- WAREHOUSE

A more detailed explanation of the "organization and use of the Manual" can be found in Section 3 which is reprinted, in part, below:

SECTION 3
January, 1979

TECHNICAL PRACTICES

ORGANIZATION AND USE OF THE MANUAL

ORGANIZATION

The CCC Technical Practices Manual contains an INDEX followed by numbered sections. The INDEX contains a Table of Contents grouped in general topic areas such as CONSTRUCTION, CUSTOMER SERVICE, HEADEND and EARTH STATION. Each general topic area is broken down into more specific numbered sections which can be located using the numbered tabs in the binder. In the INDEX each section title and number is followed by an issue number if other than the original issue. The Table of Contents itself has an issue date and an issue number (if other than the first, original issue) in the upper right hand corner of each page.

Note that each general topic area such as CUSTOMER SERVICE or STUDIO begins with a General Section and ends with a Forms, Systems, Files section followed by a System Information section. The General section of each topic area serves as an index to the individual practices in that topic area and an introduction to the material to be covered. It may also contain, by default, any material which did not fit into the other practices. The Forms, Systems, Files Section contains copies of all applicable forms, flow chart diagrams showing their distribution and use, and information regarding record retention and how they are to be filed. The System Information Section provides each individual system a place to document information pertaining to the general topic area which is unique to their system.

SECTION FORMAT

Each section covers a specific subject under a general topic area. For instance, the topic of SAFETY consists of the following SECTIONS: General, Safety Manual, and System Information. Each section is an individual Technical Practice. These are identified by a SECTION number, an issue date, and an issue number if it is not the original issue. This information can be found in the upper right hand corner of each page.

Each individual page of a Technical Practice will be numbered in the lower right hand corner of the page practice starting with one (1) for each Technical Practice. The last page of each Technical Practice will include a page number and below that the total number of pages in the practice. See the last page of this practice for an example of this. This procedure should help manual users make sure they have a complete copy of the particular Technical Practice.

The next page of this practice, Technical Practice 3, is an example of the page format used throughout this manual and contains information on the format and content of the Technical Practices.

FORMAT

The format of each Technical Practice will generally follow the structure outlined below.

* Heading (title, number, issue, subject, date, effective date)
* Purpose
* General (background)
* References
* Policy
* Procedures
* Attachments/exhibits (forms)
* Endorsements/approvals

Not all of these items are contained in every CCC Technical Practice. What must be included in every Technical Practice is a "purpose." In defining a purpose the following items should be considered:

* Why is this policy necessary?
* What does it attempt to accomplish?
* Who will read it and why?
* Whom does it affect?
* What action, if any, will/should those who read it take as a result of reading it?
* Is there any reason this policy cannot be written in imperative or narrative style rather than a legalistic-definitional style?
* If it must be written in legalistic style, is there any reason it cannot be humanized, by direct reference to the (classes of) people involved and what actions they should take?

(END OF SECTION 3 EXCERPT)

SCHEDULING

While still in the planning stages of a manual for your organization, a schedule from start to the finish, when the manual is actually issued, should be worked out. Management planning techniques such as PERT, an acronym, for "Program Evaluation and Review Technique", can prove very useful. It should be apparent now that the scope of this project is quite large, if not enormous, and it is not likely that one person has the expertise, or the time, at least in this lifetime, to write a complete manual covering every detail. For this reason the decision was made at CCC to issue a preliminary edition of the manual "as is" to selected personnel. This allowed an early introduction to field personnel, additional input on rough draft or incomplete sections, and a structure in which others within the company could organize their inputs. In addition to being issued in an incomplete state, a manual such as this is always subject to constant change, and the structure must provide for revisions. A portion of SECTION 3 dealing with manual revisions is produced below.

SECTION 3
January, 1979

TECHNICAL PRACTICES

DISTRIBUTION AND REVISIONS

DISTRIBUTION

This manual has been issued to the CCC employee listed on the front page and is for his/her use. It is not to be copied or distributed outside the CCC organization without the express consent of the Vice President-Engineering, Atlanta. The person this manual has been issued to is responsible for its safekeeping, updating with revisions issued by CCC, and its return to the Company at the end of his/her employment with CCC. The postcard form contained in the front of the manual should be returned to Atlanta when the manual is turned over to another person to ensure that future revisions or editions are directed to the proper person.

MANUAL REVISIONS

Revisions to this manual will be issued from time to time as a result of the need to cover new areas of technical operations or update old practices. These will usually come as the result of suggestions received from system personnel using the manual. Each revision will contain:

* Transmittal letter with instructions on including the new or revised practice in your manual.
* Revised "Table of Contents" (if necessary).
* New or revised Technical Practice.

After inserting the revised "Table of Contents" and new or revised Technical Practices in your manual, place the Transmittal Memo, old "Table of Contents" and any pages removed in the rear of the binder. It is suggested that the Transmittal Memo and old "Table of Contents" and any pages removed be placed in the rear of the binder. It is suggested that the Transmittal Memo and old "Table of Contents" be retained permanently and any other removed pages discarded after twelve (12) months. This will help you ensure that your manual contains all current revisions and the history of any revisions can be quickly reviewed. A sample Transmittal Memo is included as a part of this practice.

SAMPLE TRANSMITTAL LETTER

Date __________

NOTICE OF MANUAL REVISIONS

The accompanying new and revised pages, comprising of 5 sheets, (10 pages) are to be incorporated into your CCC Technical Practices Manual by making the following page removals and insertions:

REMOVE		INSERT	
Section	Issue	Section	Issue
INDEX	2	INDEX	3
7	2	7	3
25	1	25	2

It is suggested that you do not discard any pages. The pages you have removed should be filed in the rear of the binder along with this Notice of Manual Revisions. Retain this Notice and any old Index section "Table of Contents" permanently. Retain for reference purposes the other sections replaced for twelve (12) months from the date above.

(END OF SECTION 3 EXCERPT)

OBTAINING INPUT

Perhaps the best starting point in gathering information or input for the project is to conduct personal interviews with key individuals. For an MSO This would mean the Director of Engineering, Staff Engineers, Purchasing Agents, Division and Regional Engineers. At the system level this involves the System Engineer, Chief Technician, Construction Supervisor, Install Foreman and Warehouseman. They can provide valuable input regarding existing company policies, some of which may already be documented by internal company policy memorandums. This is a good time to look and listen. Do not try to rewrite the book on company operations. A Technical Practices Manual will only be successful if it is used and initially it will only be used if it reflects the present way of doing things and makes use of the valuable input received from key individuals. The manual is a bit of a public relations project and must be "sold" to its future users.

Standard industry practices such as the use of .412" and .500" aluminum cable may not require documentation in a company Technical Practices Manual, but each should be reviewed for inclusion since what is obvious to the experienced engineer may not be to the CATV newcomer. Several organizations issue standards in the United States, including the NCTA, IEEE, FCC and the ANSI (American National Standards Institute). Those standards which affect CATV should be included at least by reference. CATV manufacturers also have a wealth of information which they have made available to the industry.

Correspondence and person-to-person interaction with other cable operators can provide invaluable input and help prevent you from "reinventing the wheel." Much of the background material for the Technical Practices Manual came as a result of participation by Cox Cable engineers on the NCTA Engineering Advisory Committee (EAC) and Operating Procedures Subcommittee.

ORGANIZING THE INPUT

Once the input reference material had been gathered and separated into the general topic areas previously discussed, it became necessary to expand on these general areas. Subdividing the manual into many sections allows the user faster access to the specific information he needs. An additional benefit for the writer is that it breaks up the project into manageable "bites" which can be handled one at a time. It also facilitates issuing a partially completed manual since missing sections can be added to the framework at any time.

Appendix A is a complete listing of the Table of Contents for the Technical Practices Manual. The topic areas are, for the most part, self-explanatory, with the exception, perhaps, of the DISASTER PLAN. The sections contained under this topic area are contingency plans in the event a part of the system was destroyed in whole or part by a manmade or natural disaster. Imagine, if you will, the usefulness of preplanning should your headend be destroyed for any reason.

Because of their bulk and necessary wider distribution the Contruction Manual, Technician's Manual, Installer's Manual, and Safety Manual are not included in the Technical Practices Manual but only referenced.

MECHANICAL PREPARATION

How to package the finished product is the next step. Remember that this involves some public relations aspects in addition to the more mechanical considerations such as number of pages. You must "sell" the manual to its future readers. A professional looking binder and approach to page layout will increase the useage of the manual. Since frequent revisions are expected a standard three-ring binder for an 8½" x 11" page was chosen. A 2" wide binder is a good choice since bigger binders are harder to use and their bulk usually means wrinkled or torn pages. Plastic "sheet protectors" should be used at the front and rear of the binder. Pockets on the inside covers can provide a handy place to store other written material. A second 2" wide volume is anticipated, in the near future, to handle the large amount of material. A distinctive printed cover sheet was produced which was cut into three sections corresponding to the front and rear covers and spine of the binder. These were then "heat sealed" to the binder using a clear plastic. This produces an attractive and durable binder. This type of binder is expensive, five to seven dollars each, even in quantities of fifty. If only a few copies are required a standard binder is recommended. It can be customized, inexpensively, by printing directly on the vinyl cover.

The tabs are custom printed with a complete set containing 109 tabs titled INDEX and 1, 2, 3....107, and 108. Each tab is plastic coated and ring binder holes are plastic reinforced. The tab sheets themselves are of paper stock considerably heavier than that used to print the pages. All of this should help to extend their life under heavy useage. These customized tabs are very expensive (approximately $55 per set) in small quantities, and a printer considers 50 sets a very small quantity! If you are producing only a few volumes, use clear plastic tabs which can handle insertable titles.

The number of pages in the initial edition was estimated to be 400. Several methods of reproducing these were considered, including typesetting and printing, photo-offset printing of typed copy and use of the office copying machine. Typesetting produces very professional copy with left and right justified margins. It also allows approximately a 50% reduction in the page total. For comparison purposes typesetting costs approximately $25 per page when printing five hundred (500) pages on two hundred and fifty (250) sheets, i.e., printed front and back. Typesetting was rejected as too expensive and lacking the flexibility to issue small revisions later which matched the original printing style without going back to the printer. The office copying machine is the least expensive alternative for small quantities but copies lack the professional "look" that was being strived for. An IBM Selectric typewriter with a carbon ribbon was used to prepare copy which was reproduced using a photo offset technique. Photo offset printing costs about $8 per page in 250-page quantities. The heatsealed binder, printed and plastic reinforced tabs and the photo offset pages produced a finished and professional appearance.

CONCLUSIONS

A continuing effort is underway to complete sections of the manual and add substance to the skeletal framework described in this paper. Farming out of certain sections to inhouse experts in a particular field is being pursued in order to reduce the enormity of the task. Even if you have little desire to produce a formal Technical Practices Manual, it is suggested that, perhaps, the Table of Contents could serve as guide in filing and retaining the memorandums issued in your organization. After a period of time an accumulation of information should occur which will provide you with a fairly concise and complete technical operations guide.

A possibility for future work in this area might involve the National Cable Television Association (NCTA) or Society of Cable Television Engineers (SCTE) providing binders, tabs and a partial set of technical practices as a sort of "seed" kit to interested cable operators. NCTA or SCTE members could provide information leading to the issue of suggested technical practices on a regular basis. This might help produce a reference handbook in the cable industry akin to the National Association of Broadcasters (NAB) Engineering Handbook which, in its several revisions, has served the broadcast industry so well.

ACKNOWLEDGEMENTS

As an often times reluctant author, I would like to thank Dick Hickman, Vice President-Engineering, Cox Cable Communications, and Jerry Partch, Director of Engineering, Liberty Communications, for their support, inputs and critical evaluation of the finished product.

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APPENDIX A

TECHNICAL PRACTICES

TABLE OF CONTENTS

EDUCATION - THE MEANS TO AN END

Thomas J. Polis

Magnavox CATV Systems, Inc.
Manlius, New York

We are an industry which is currently enjoying a fantastic growth rate. With the advent of Pay Cable, De-regulation and the increasing use of the system to provide services such as alarm systems, Peak Power Management and Data Communications, we find ourselves faced with an enormous problem: "The Lack of Effectively Trained Personnel." In other industries, this problem can be reduced by going to the colleges of our nation and select personnel from a large graduating roster. Whenever any segment of our industry has made this attempt we have all received the same basic question: "What is a CATV?" One must remember that a successful Institute of Higher Learning is based on the employment success of its graduating students. Until the industry can demonstrate this all important employment success rate, the institutions will not turn the corner and we will continue to play second fiddle to other industries.

Before we can begin to take steps to correct our training problem as an industry, we must first define the problem and look for common denominators as well as evaluate what the various current opportunities are.

When we analyze the problem of education and training we find that there are three specific areas to be considered:

1. Operating System Technician

   For the most part, these individuals have been promoted from lower job levels. A great deal of them have no formal training in electronics. Their knowledge has been developed through industry seminars and on the job training.

2. A.A.S. Graduates

   I refer to those people who are graduated from a formal 2-year program of electronics studies. Our industry does not enjoy very many entrances of these people as the computer industry dominates the on-campus interviewing and many students are not aware of the cable industry's opportunities.

3. A.A.S. or B.S.E.E. Graduates Operating as Chief Engineers or Technicians

   These people have advanced via their formal background and job experience. Their cable TV knowledge has come from industry seminars, trade shows, workshops and SCTE seminars.

All three areas have some common denominators:

1. All have the desire to learn.

   Given the opportunity to attend classes or seminars, not one would refuse.

2. All would like more "hands-on" training.

   Questionnaires from seminars indicate that this is a very important factor.

3. All are weak in test equipment knowledge.

   This is related to the operation and theory of test equipment commonly used in the cable industry (not knob twisting).

Armed with this knowledge, we can now begin to evaluate our options.

Problem Area #1

This is probably our most critical area in our operating systems. The day to day routine maintenance of the system is in the hands of this group. System reliability is most dependent on the technician's knowledge.

At the present time, there are very few programs which will produce the results required. Home study courses, such as those offered by N.C.T.I. are the main source of training. Other correspondence courses on general electronics are also available but you must be very careful which one is selected.

In recent months a joint effort has begun between the S.C.T.E. and the University of Wisconsin to provide the basic knowledge in electronics which is so necessary for a fully developed technician. I have great hopes for this program and am sure that under the watchful eyes of Judy Baer and Jack O'Neill that it will be a success.

The program will cover a lot of territory and will require ten days of a technician's time. Some people, when surveyed, felt that the time would be a "stumbling block" indicating that they cannot afford to give up ten days of a technician's time. During the course of a year a system operator will send his technicians to one or more two to three-day seminars. The unfortunate thing is that without the basic understanding, very little if anything is gained by the technician.

Problem Area #2

We have been spending great deals of money, as an industry, on an annual basis to hire technicians. Most of the dollars are spent in recruiting technicians from other operating systems.

We must take steps to bring new technicians into our industry. During a recent trip to many New York State Community Colleges, I have found that our industry is little known. One school which graduates students trained specifically in communications electronics and augments its training with an FCC First Class License Program was not aware of the requirements of our industry nor the advances we have made in two-way communications, data communications and space communications.

The only cure to this problem is to boast our industry outside of our industry. School visitations, on-campus recruiting, and invitations to placement directors and educators for plant visits will go a long way.

Judy Baer of the S.C.T.E. is preparing a document entitled, "Consider a Career in Cable TV" which will soon be available for circulation.

Problem Area #3

For our industry to advance and create additional revenue and gain the recognition it requires, we must provide training for our more qualified engineers. Currently seminars are the only place for this activity. The problem is that seminars are now directed at the intermediate technician and in most cases provide only knob twisting exercises.

Specific workshops are needed where concentrated effort is given to one or two topics (ie: cross-modulation or composite triple beat) which are peculiar to our industry.

Documentation

If you have ever attempted to find documentation on a specific topic matter related to Cable TV, you already know the problem.

A great deal has been accomplished by the S.C.T.E. in this area but we have only scratched the surface.

One additional step which could be taken is to form a documents center (possibly via the S.C.T.E.) to which papers could be submitted concerning technical matters. At the present, only papers which are presented at shows such as the National, S.C.T.E. Reliability Conference or other major shows are published. (Notwithstanding trade periodical publications, of course.)

System Training Programs

Many systems in an effort to improve the competence of their technicians, have implemented their own training programs. Many of these programs are very good in their content but are lacking in the manner of presentation.

Many universities around the country have departments which could assist in these programs. The Syracuse University, for example, has a "Center for Educational Development" which we at Magnavox have used to assist us in our employee training programs. We determine the content of a program and they (S.U.C.E.D.) develop the educational technology for presentation and assist us on measuring the results of the program.

Another Option

Many schools now have "Co-Op" programs. These programs are designed to put students in the field for work experience during their studies.

The program is set up with the employer so that the student will work for a period of time (3 to 6 months) and then return to full time studies for an equal amount of time. The benefit is that the student can readjust his course of study to develop skills which he will require in his career selection.

Many states offer financial aid to companies which are involved in these types of training activities paying in some cases as high as 50% of the student's income.

Summary

I wish I could say that there are 100 or more places where you could sent your people for training related directly to CATV technology in the United States and then list them. Unfortunately, there is no such possible list at this time. We have taken some major steps forward with the involvement of the S.C.T.E. and the University of Wisconsin, but if the entire industry is not involved and get behind this type of program and future required programs, we will all be saying "What Ever Happened To?",about our options in training.

I have stated before, and I feel it necessary to state again, that we as an industry have moved from an entertainment service providing television pictures to the home into the "Broad Band Communications Service" which can, and in some cases now does, provide an almost unlimited number of services into and out of the subscriber's home.

Without properly qualified technicians and engineers, the fruits of the past 30 years' efforts will die on the vine.

EIRP OF THE SATCOM CABLE TELEVISION SPACECRAFT

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This paper will describe the field test program undertaken by RCA Americom to establish the EIRP of its F1 Spacecraft now in orbit. This satellite is used primarily for cable television program distribution. The study was performed as a service to the industry in order to provide actual EIRP measurements as opposed to calculated predictions. The results of that exercise will be presented and suggestions for prudent system designs for users of the Satcom Spacecraft will be put forth. This paper will also address the design of the Americom F3 Spacecraft to be launched in the fourth quarter of 1979. Enhancements incorporated for the benefits of the cable television community will be presented and projected contours will be shown. RCA Americom plans to provide actual EIRP measurement results for future satellites used by this industry.

Background

Until June of 1978 all programming for the cable television industry's receive only video services had been provided on the RCA F2 spacecraft located at 119^{o} West Longitude. However, because of the phenomenal growth being experienced by the industry and the even greater progress anticipated for its future, it became obvious that greater space segment capacity was required. A decision to move the cable traffic from the F2 to the F1 spacecraft located at 135^{o} West Longitude was made early in the first quarter of 1978. The purpose of this decision was to make available a greater number of transponders for program material since 12 of the 24 transponders on F2 were dedicated to Alaskan service.

The transfer of the cable traffic was successfully completed by June, 1978. As expected, difficulties were encountered by some cable systems, particularly in the southeastern states, where the signal level from F1 is lower than from F2. In a number of these locations, the measured F1 signal levels appeared to be lower than the calculated values which had been published.

These difficulties led to a decision to undertake a systematic measurement program which would result in a set of measured EIRP contours. These contours would provide cable operators, consultants, and earth station manufacturers more precise data upon which to base the specification of earth station G/T performance at specific locations. This is a useful service to the cable industry, and RCA Americom plans to continue it as future satellites are launched which will serve cable systems.

This paper describes the F1 and F2 measurement program, but before providing the details of that effort it is worthwhile to consider what EIRP is and the reason for its importance.

EIRP

EIRP is an acronym for Effective Isotropic Radiated Power. An isotropic radiator is one which radiates its power equally in all directions. However, a communications satellite's energy is concentrated by a parabolic antenna so that illumination is restricted to a specific desired portion of the earth's surface. EIRP is computed by adding the output power of the final amplifier (Traveling Wave Tube) of the transponder less any losses due to waveguide, coax, and switches, etc. to the gain of the satellite antenna in a particular direction. Thus, EIRP is the power that would have to be radiated by an isotropic radiator to provide the same illumination in a given direction as is accomplished by the spacecraft. The line connecting all points of equal EIRP in a projection is called a contour. It is not the power at the surface of the earth, which will vary due to path loss differences, atmospheric absorption, weather conditions, pointing accuracy of the antenna, and other factors. Received signal strength must be calculated for each location taking such factors as may be required into account. Additionally, certain locations may suffer from blockage due to trees, multipath effects, terrestrial interference, and increased antenna noise temperature, all of which become worse as the elevation angle of the receiving antenna is reduced. Each receiving earth station and system must be responsibly engineered with its unique requirements in mind. The prudent business man will insure that his system is designed to operate satisfactorily (i.e., with adequate margins) not only with a specific desired spacecraft but with all spacecraft it is potentially likely to access. Using approximations and rules of thumb is done at the system owner's peril.

Now that we know what EIRP is, why is it so important?

When reduced to its essence, communications systems engineering consists of using power and bandwidth to provide a desired signal quality to an end user. The spectrum available for the cable broadcasting services considered in this paper is well known and determined by the transponder bandwidth (nominally 36 MHz).

Parameters such as top modulating frequency and peak deviation have been standardized. Thus, the Modulation Improvement, that contribution to signal quality provided by factors of deviation and bandwidth, is essentially fixed. The other contributor to signal quality is the signal strength or power in the communication channel and this is directly related to the sum of EIRP from the spacecraft and the G/T of the earth station.

G/T is a figure of merit for satellite earth stations and refers to the receive gain of the earth station antenna at a given frequency less the total system noise temperature both expressed in dB.

Assuming a given modulation (FM) improvement to achieve a target signal quality (signal to noise ratio) the EIRP and G/T will vary inversely, i.e, if the EIRP is increased by 1.0 dB the earth station G/T may be decreased by 1.0 dB to maintain the same performance. Conversely a lower EIRP requires a corresponding increase in G/T. This is the pivotal reason for EIRP's importance; because G/T is improved in one or both of two ways. Either through an antenna with higher gain (a larger aperture), or a receiver with a lower noise temperature. Both of these options cost money. Thus, EIRP is inversely related to the cost of receive only earth stations; if it goes down the cost to maintain the same level of signal quality goes up, and vice versa.

Field Test Program

In response to the numerous questions raised about in-orbit performance of the Satcom spacecraft and because our internal test effort showed some cause for concern, RCA decided to undertake an EIRP field measurement program. The objectives of this program were:

- o Establish the EIRP contours by actual field measurement.
- o Establish procedures and techniques for measuring EIRP of future RCA spacecraft as an aid in verifying that in-orbit performance meets specifications.

To assure a stringent test effort, we secured the services of an established consulting firm, Compucon, which is well known to the cable community.

Discussions were initiated with them to secure a test concept and procedures and it quickly became apparent that nothing of this kind had ever been attempted in the commercial satellite business. While field test programs had been done, none had been performed to the level of accuracy required to assure that this effort would be meaningful. Initial studies indicated that the accuracies achievable were on the same order of magnitude as the difference between actual and predicted that we were looking for. When we began, achievable accuracy was ± 1.6 dB. This was successfully reduced so that the overall accuracy of the Phase I portion of the test was ± 0.7 dB and for Phases II and III the corresponding figure is ± 0.6 dB.

The services of Home Box Office (HBO) were enlisted to act as industry representatives and HBO personnel were invited to participate as witnesses at all test sites throughout this exercise.

Methodology

The program is to be accomplished in three phases as shown in Figure 1.

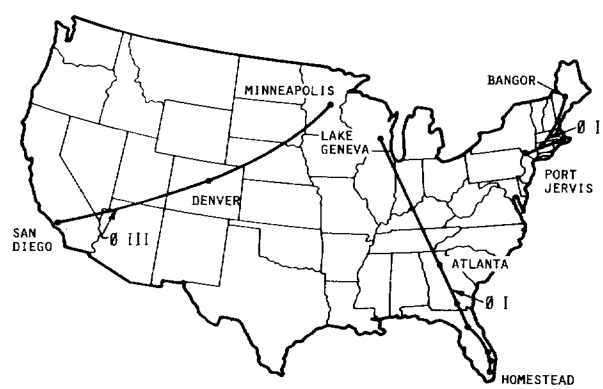

Figure 1. EIRP Test Locations

Phase I consisted of measurements along a radial beginning at the RCA earth station at Lake Geneva, Wisconsin (slightly north and west of Chicago) and extending down to the tip of Florida. The locations at which measurements were taken or are contemplated can be found in Table 1.

Table 1. EIRP Test Locations

Phase I	
Lake Geneva, Wisconsin	
Glasgow, Kentucky	
Atlanta, Georgia	
Valdosta, Georgia	
Orlando, Florida	
Fort Pierce, Florida	
Fort Lauderdale, Florida	
Homestead, Florida	
Phase II	
Port Jervis, New York	
Plainville, Connecticut	
Hyannis, Massachusetts	
Bangor, Maine	
Phase III (Proposed)	
Minneapolis, Minnesota	
Omaha, Nebraska	
Denver, Colorado	
Flagstaff, Arizona	
San Diego, California	

Chronology

The first discussions were initiated with both Compucon and HBO in July, 1978 with a view toward accomplishing an expeditious test program. A test procedure was established and agreed to by all parties and efforts commenced to obtain the necessary equipment with the required calibration accuracies. To say that considerable difficulty was encountered at this step would be an understatement.

The tight tolerances necessary to assure a valid test, together with the fact that field tests in the past had not been accomplished to such rigid specifications, combined to cause several delays to the project. Problems were experienced in acquiring microwave test equipment because of the demands placed upon manufacturers by a booming industry and in accomplishing the required calibration in a timely manner. Eventually, a test bed was established in Dallas in September of 1978 and a week of dry runs were accomplished to prove-in performance and calibration accuracy.

The first phase of the field test effort was completed in November with Compucon's report submitted in late December and the field test portion of Phase II was finished in mid-March. It was unfortunately delayed because a modification to the test setup resulting from wearout of certain RF components necessitated calibration of the replacement item. At this writing (March, 1979) we are in the process of preparing the Phase III test to obtain data on a radial from Minneapolis to San Diego.

Equipment

The test hardware consisted of a 4 foot parabolic metal antenna, manufactured by Terracom, a low noise amplifier from Scientific Communications Inc., signal generator, power sensor, power meter, spectrum analyzer, and associated couplers, cables and switches from Hewlett-Packard. The antenna was modified to permit rotation of the feed so that vertical and horizontally polarized transponders could be easily measured and so that adjustments could be made for variations in local polarization angle.

The antenna was calibrated at Chu Associates in Massachusetts, while the bulk of the remaining equipment was calibrated by Hewlett-Packard. A block diagram of the test configuration is shown in Figure 2.

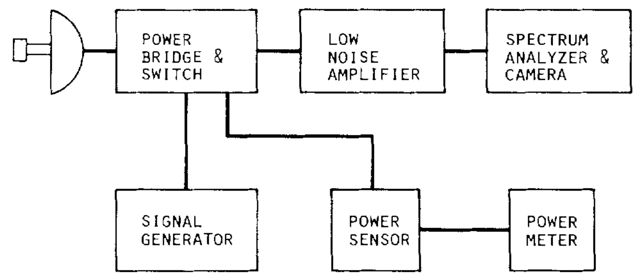

Figure 2. Equipment Block Diagram

The measurement used is a standard one in satellite communications called RF substitution. This method provides excellent accuracy in the detection of unknown low level signals. The parabolic antenna, LNA and spectrum analyzer act as the detection and storage units and the signal generator, power bridge and power meter provide the known source. The unknown saturated (maximum power output) carrier is received from the spacecraft and the system is adjusted to observe peak signal strength. It is then stored on the scope of the spectrum analyzer. A known signal is inserted into the front end of the LNA and adjusted until it is equal in level to the stored image of the carrier received from the satellite. The injected signal is known because the signal generator, power meter, power sensor, bridge, and all cabling have been precisely calibrated. This technique effectively measures the received signal strength at the input to the LNA thereby eliminating it as a source of error. Knowing all losses through the system and the receive gain of the test antenna, one can determine the received signal strength at the input to the antenna. Computation of the path loss and atmospheric absorption losses at the location under consideration permits one to extrapolate back to the EIRP from the spacecraft. The entire test setup was transported from site to site by truck and whenever possible in Phase I the measurements were performed at the headend facilities of a local CATV company or in the parking lot of a local motel.

RFI analyses were performed for each of the test locations to assure that no tests would be taking place in areas of heavy terrestrial interference which might becloud the results. Tests were run from 2:30 AM to 2:30 PM and special emphasis was placed upon measuring HBO transponders 20, 22, and 24 at each location. Four sets of measurements were taken on each transponder throughout the test period with a view toward washing out local atmospheric effects.

A standard gain horn was used for side by side comparison with the 4 foot antenna prior to starting a test run. This was done to check relative gain differentials thereby making sure that the parabolic antenna had not suffered any damage which would have caused its gain to change and invalidate the data. In no instance was any change discovered.

Throughout the test program, personnel from RCA Laboratories provided guidance on techniques for improving accuracy but did not take part in actual test efforts.

Results

Since the test program is not yet concluded, the results presented herein are final only for Phase I.

Phase I: (Chicago to Florida)

- o On Spacecraft F1 the measured EIRP (mean of all transponders measured) is 1.6 dB below predicted values.
- o On Spacecraft F2 the measured EIRP (mean of all transponders measured) is 1.2 dB below predicted values.
- o The measured differences between F1 and F2 agree very closely with calculated differences.
- o No other anomalies in spacecraft performance were discovered.

Phase II: (Northeast U.S.)

- o The field test portion of this effort was completed on March 19, 1978. Data reduction exercises are, as of this writing, under way at Compucon. These results will be presented as an appendix to this report.

Analysis

The predicted EIRP values provided by RCA to the cable community were calculated analytically from data accumulated during range tests of the spacecraft antenna systems made on the ground prior to launch of the spacecraft. The differences between measured and predicted values thus far discovered during this test effort are believed to arise from errors in the range tests performed by the spacecraft manufacturer as well as the adverse effects of the space environment resulting in some degradation of component performance such as thermal distortion of the antennas.

Future Efforts

The results to date of this program have been taken into account in the design of the F3 spacecraft and some comments about it are apropos. The elevation angle of the antenna platform will be depressed 0.6 degrees from its value on the F1 satellite. This is being done to improve performance to the low signal areas of the southeast.

The contour shown in Figure 3 is a preliminary depiction of the minimum expected performance of the F3 spacecraft at 132^{o}. The F3 will be equipped with four redundant Traveling Wave Tubes (one for each bank of six transponders). In the event of a failure of a primary transponder, the redundant unit would be switched in. This contour represents minimum performance even under the failed condition. It is expected that most transponders will provide performance superior to that shown here. However, until this is conclusively established in range tests this contour should be used for system planning purposes.

Furthermore, we anticipate a program analogous to the one described in this paper as part of a verification of in-orbit performance of the F3 spacecraft after launch and prior to commissioning for service. Revised contours and predictions of EIRP to specific locations will be provided to the cable community and manufacturers once actual RF performance of the satellite has been verified.

Certain other enhancements are being included in the F3 design in order to provide superior service. These include bigger (17 amp-hour batteries) which will permit reduced depth of discharge during eclipse operations, thereby prolonging battery life and improving spacecraft reliability and performance. Improvements in the attitude control system are being made in order to have a more stable platform in orbit. Modifications to the thermal design are being incorporated to improve operating characteristics.

Conclusion

RCA Americom and Compucon have attempted in this test program to accurately report the results and characterize performance of the Satcom spacecraft. The lessons learned will be used in the design and implementation of future Satcom systems to insure that the design criteria provided for use by customers will always prove satisfactory in the future.

Our sincere thanks and appreciation to Messrs. Keith Evans, Tom Rea, Don Pidgeon and Helmut Schwarz, whose highly professional efforts contributed to the success of this test program.

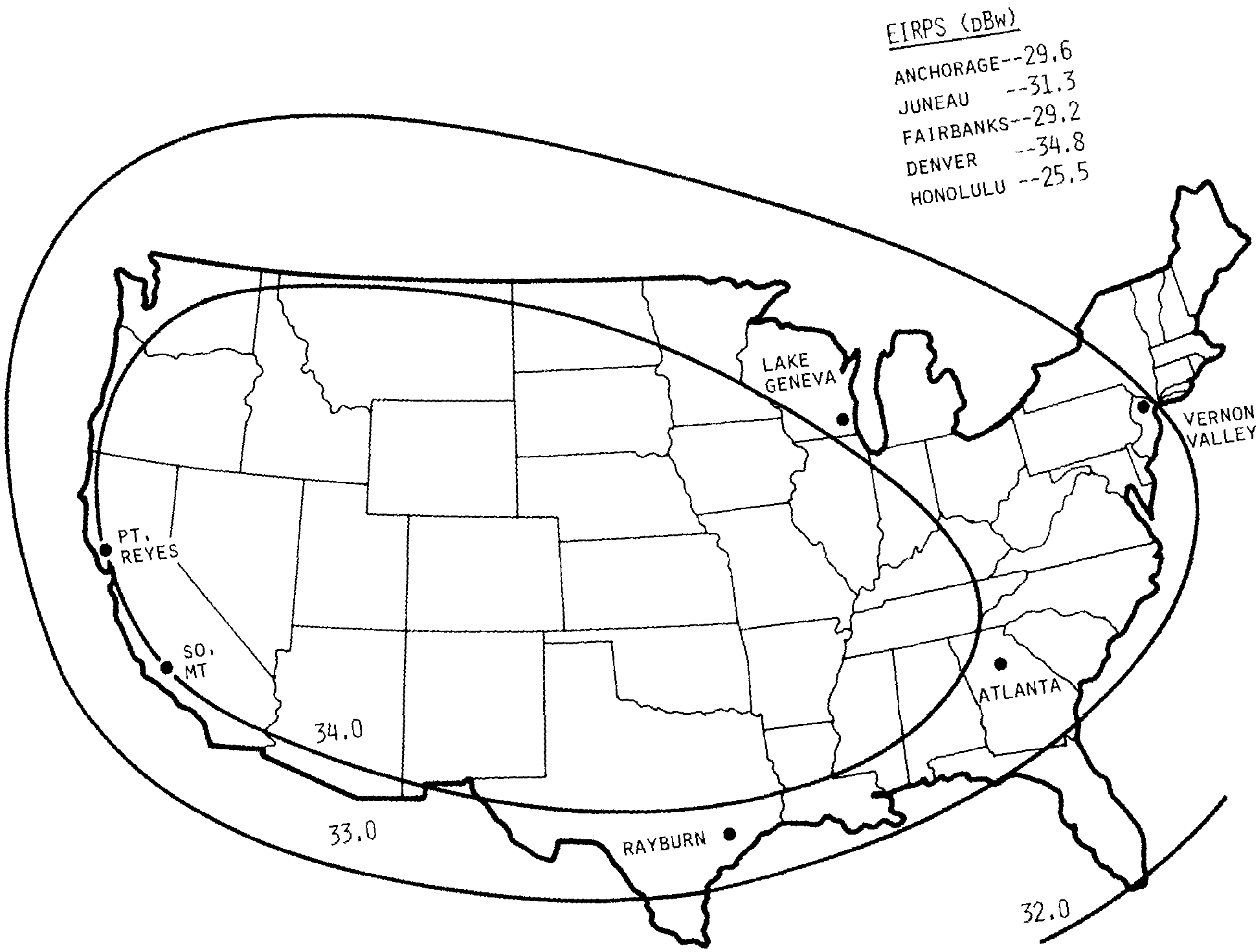

FIGURE 3. F3 SPACECRAFT AT 132° EIRP CONTOURS (PRELIMINARY)

INSTALLATION AND FIELD OPERATION
OF AN 8 KM FIBER-OPTIC CATV SUPERTRUNK SYSTEM

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May 20-24, 1979
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ABSTRACT

The BCN Fibre Optic experiment in London, Ontario is the first major fibre optic CATV supertrunk installation in North America.

The link transmits 12 NSTC color television channels and 12 FM stereo channels over an eight fibre cable 7.8 km in length. Audio, video and FM signals are digitized and multiplexed into a single 322 Mb/s bit stream modulating an injection laser diode transmitter.

This presentation describes the installation and field operation of the link, outlining construction problems and their solutions and describes the field maintenance procedures employed. Information is also presented on the reliability and performance quality of the system obtained to date.

Videotape highlights illustrating cable installation practices, splicing, connectorization and electro-optics installation and maintenance will be shown.

1.0 INTRODUCTION

Field trials of fibre optic technology are appearing through the communications industry and around the world. Major telephone companies have installed interoffice trunking and subscriber services using fibre optics. Power utilities have installed fibre optic data transmission systems in their high EMI environments.

The Canadian cable television industry has sponsored a major fibre optic supertrunk system in conjunction with a major Canadian cable manufacturer and with the Canadian Federal Department of Communications. The purpose of the field trial is to assess the potential impact of fibre optic technology when specifically applied to the needs of the CATV industry.

This paper describes the actual experiences as the system has been designed, manufactured, installed and commissioned then outlines the experiments that will be conducted during one year of operation by an operating CATV company.

2.0 PROJECT DESCRIPTION

2.1 The Consortium

BCN Fibre Optic Inc., formed from a group of companies, in co-operation with the Canadian Federal Government, is performing field tests on the first major CATV fibre optic trunk in North America.

The consortium is formed by Canadian Cablesystems, Rogers Telecommunications, National Cablevision, Cable TV, Premier Cablevision, and Western Cablevision in conjunction with Canstar Communications a division of Canada Wire and Cable Company Limited.

2.2 Project Status

7.8 km of fibre optic cable has been installed in London, Ontario, from the local TV station to the hub of London Cable TV.

The Electro-optic terminal equipment and two repeaters have also been installed in preparation for the start of the commissioning tests in March.

2.3 System Description

The fibre optic trunk uses graded-index optical fibres having a bandwidth-distance product in excess of 600MHz-km and attenuation less than 8dB/km. Eight small optical fibres (0.005-inch diameter) are formed into a single multifibre cable providing transmission capacity for a full 15 TV channel supertrunk in a cable less than 1/2-inch in diameter.

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

Fibre No.	*Function*
1, 2	Each fibre carries three high quality digital baseband TV channels, three digital FM stereo channels plus parity and housekeeping data.
3, 4, 5	Each fibre carries two high quality digital VSB TV channels, two digital FM stereo channels, plus housekeeping data.

6 Fibre carries three channels of high quality digital baseband in the opposite direction (i.e. from distribution hub to head end).

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

All signals are converted into PCM digital form before going on the cable. To add to the information from the trial, two different approaches are used for the video encoding. "Baseband encoding" (BBE) transmits a signal through the fibre representing the baseband picture alone. "Vestigial sideband encoding" (VSB) transmits a signal representing the whole video composite, including the picture, the audio, and the color subcarriers. The BBE signal is simpler; but the terminal equipment for VSB is simpler and cheaper since it lacks modulation and demodulation equipment. The trunk will allow side by side comparison of the two systems.

Six of the video signals are BBE. Each one is sampled at 10.74MHz, three times the color subcarrier frequency. The encoding uses a 10 bit format. Eight bits are for the picture, the ninth for program audio and sync information, and the tenth for parity bits, one or two data channels.

Three BBE signals are multiplexed into one 322.2 megabit per second stream, along with the data, FM stereo, etc. Each of fibres one and two carries this signal to account for six video channels, six FM stereo channels, plus data, etc.

The VSB signals need a higher sampling rate to accommodate the 7MHz bandwidth of the composite signal. The PCM encoding produces a 161.1 megabit per second bit stream from each VSB signal, which again includes "housekeeping" bits data, and FM stereo. Two of these are multiplexed into the single 322.2 megabit per second bit stream; and each of fibres three, four, and five carries this signal, accounting for the other six video channels, six FM stereo channels, etc. Fibre six carries the three upstream video channels, in BBE form.

3.0 OBJECTIVES OF THE FIELD TRIAL

The field trials set out to determine the practicality of aerial fibre optic installation, using standard techniques to construct the fibre optic supertrunk. Two repeaters in the 7.8km length of the fibre optic cable, result in a comparable signal to that achieved using nine conventional co-axial trunk amplifiers.

The fibre optic cable is one half inch in diameter as compared to the standard one inch, co-axial type. The abundance of raw material for the glass fibre and its resistance to outside interference, makes fibre optic transmission an important part of future CATV installations.

This test link will determine the performance of fibre optic hardware under standard cable TV use:

1) Buried and aerial cable.

2) Fibre connectors.

3) Cable splices.

4) Headend and hub equipment.

5) Electro-optic repeaters.

A series of tests lasting one year will gather information about performance and reliability as well as the serviceability of the link.

4.0 ELECTRO-OPTIC SYSTEM: MODULE DESCRIPTION

The head-end and hub electro-optic equipment consists of combinations of seven modules. These modules are:

(1) Baseband video encoder

(2) Baseband video decoder

(3) VSB encoder

(4) VSB decoder

(5) FM stereo encoder

(6) FM stereo decoder

(7) Link test and maintenance unit

The various modules can be interchanged between the head-end and the hub to configure the fibres in the link for either upstream, downstream and loop through transmission.

4.1 Baseband Video Encoder/Decoder

The baseband video encoder and decoder are designed to transmit three baseband video, 3 digital FM stereo, and two asynchronous digital signals over a single optical fibre. The video data is digitized, multiplexed with digital data and transmitted as a 322 m/bits digital optical signal.

The baseband video system is composed of two independent rack mountable assemblies. The encoder drawer digitizes 3 baseband video inputs, and three audio inputs and combines them into a single data stream along with 3 digitized FM inputs and 2 asynchronous digital data inputs. The decoder drawer reverses this procedure, demultiplexing the various digital data stream and, in the case of the video and audio, converts the signals to their audio forms.

4.2 VSB Encoder/Decoder

The VSB encoder and decoder are designed to transmit 2 VSB video, 2 digital FM stereo and 2 asynchronous digital signals over a single optical fibre. The video data is digitized, multiplexed with the digitized FM stereo and asynchronous digital data and transmitted as a 322 mbps digital optical signal.

The VSB system is composed of two independent rack mountable assemblies. The encoder drawer digitizes 2 VSB video inputs and combines them in to a single data stream along with 2 digitized FM inputs and 2 asynchronous digital data inputs. The decoder drawer reverses this procedure, demultiplexing the various digital data streams and, in the case of the video, converts the signals to their analog forms.

4.3 FM Stereo Encoder/Decoder

Each drawer is capable of encoding (decoding) up to six FM stereo IF signals. The 10.7 MHz signal applied to the encoder is downshifted and digitally encoded into a serial bit stream of 9 bits per sample. This serial bit stream is multiplexed with others and sent to one of Baseband video or VSB encoders. The de-multiplexed bit stream recovered by the Baseband video or VSB decoders is applied to the input of a decoder where the signal is de-multiplexed, reconverted to analog form and upconverted to a 10.7MHz IF output.

4.4 Link Test and Maintenance Unit

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

A transponder module located in every repeater unit enables the LTMU and repeater subassemblies 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.

5.0 FIBRE OPTIC CABLE DESIGN AND FABRICATION

Little was known of the requirements for fibre optic cable design at the start of the project. The final design has evolved as the result of actual production and test of various cable types.

5.1 Optical Fibre

The prime considerations in selection of optical fibre for the project were:

1) optical characteristics: attenuation, bandwidth or pulse dispersion
2) strength: able to withstand cabling, installation, operational environment
3) availability: required quantity, tested to required specification in time for the project
4) cost.

5.1.1 Optical Characteristics

The fibre selected was the Corning Glass Works product 6060 which is a graded index, outside vapour phase deposition (OVPD) type, with 6dB/km attenuation and 600MHz-km bandwidth. The industry has not yet established standards for measuring these parameters although Corning is attempting to lead the way. When comparing measurements it is important that the measurement technique be understood. Using different techniques, the same fibre will give a wide range of attenuation results. With 6dB/km attenuation and 600MHz/km bandwidth, each fibre is capable of carrying 2 or 3 complete CATV signals.

5.1.2 Strength

The strength of fibre is given as a probability of breakage if a known force is applied. The strength characteristic curve is generated empirically and is given as a guide for cable design. Each fibre is subjected to a 100% screen test of 25,000 psi. That is, each fibre is known to have had 25,000 psi applied continuously during the manufacturing process. Should a break occur, the fibre would be scrapped. With 25,000 psi as the known ultimate limit, 10,000 psi should be a safe design load for cable manufacture. The cable manufacturing industry expect that the proof test will be raised to 50,000 psi or 100,000 psi in the future.

5.1.3 Availability

At the time that the project was formed, Corning had the only proven capability to supply fibre of the required quality in the required quantities. Fibre at 6dB/600MHz falls into the "premium" portion of their manufacturing yield.

5.2 Cable Design

Various designs were considered, that would enable fibre optic cable to be manufactured, and installed with a maximum load of 10,000 psi on the fibres themselves. The loose buffer tube approach was settled on at an early stage. The fibre lies loose in a protective buffer tube so that minimal stresses are applied to the fibre. The buffer tubes are then stranded around a central strength of anti-buckling member. From this point, there are several possibilities which relate to basic cable construction rather than fibre optic cable construction.

1) Figure Eight Self Supporting Cable: This structure was not attempted, primarily because of the unpredictable wind and ice loading effect of the web joining the member of the cable core.
2) Concentric Self Supporting Cable: Test lengths of this type of cable were made where the support strength comes from spring steel members stranded around the fibre optic cable core. The strength characteristics were adequate but the handling and installation difficulties were extreme.
3) Lashable Cable: The final design selected for the project consists of the basic cable core protected with an Alpeth Sheath (aluminum bonded to a polyethelene outer jacket) for strength and as a moisture barrier. This cable is lashed using a conventional lashing machine to a conventional messenger wire.

5.3 Aerial Cable Specification

Performance specifications were developed over a period of months to reflect the operating environment in London, Ontario. The specifications were given to a number of cable manufacturers as a guide for cable design.

5.4 Cable Characterization and Test

The tasks of measuring the characteristics of cabled fibre and testing over the operating temperature range were greather than originally planned. The time consuming aspect of testing is the temperature cycling where it takes up to 24 hours for the ambient temperature in a cold chamber to penetrate to the core of a coiled cable. The designs tested were found to be adequate over the extreme temperature ranges.

6.0 CABLE INSTALLATION

The cable installation consists of 6.8km of aerial construction and a one kilometer section of buried cable making up to total 7.8km length. The installation parallels London Cable TV's existing 1" air dielectric co-axial supertrunk.

6.1 Buried Section

The buried section extends from the head-end location through a new sub-division and under a major street to the first pole span of the aerial construction. The cable used for the buried portion contains heavy steel armouring making the cable very rugged (over 1,000 lbs safe pulling tension) at the expense of adding to its weight. No special precautions were taken to provide a moisture barrier for this section of cable. This will enable investigation of the effects of moisture ingress in the cable. The cable has suffered no ill effects after 10 months of weathering.

The cable installation technique employed was direct burial in a trench roughly one meter in depth. A chart recorder was used to monitor attenuation of the fibre during burial and for a period of one month after installation. There were only very minor variations in attenuation noted during installation, which were directly related to handling of the cable. Attenuation changes were unnoticeable after the cable was installed.

6.2 Duct Installation

There were several short duct pulls required in the installation under roadways, railway tracks and into the head-end and hub locations. All duct pulls were less than 100 meters and were completed without damage to the cable. Pulling tension never exceeded 200 lbs. even where two ninety degree bends were pulled around one location.

6.3 Aerial Installation

The aerial portion of the supertrunk was installed using aerial cable pulling (with ropes and rollers) and direct lashing techniques (lashed directly from cable reel trailer to strand on streetside construction).

Equipment used to install each section of the cable was standard. In fact, the installation crew was not specially chosen; they were installers with years of co-axial cable experience.

The majority of the aerial installation was overlashed to existing strand. One kilometer was lashed to separate strand for comparison. Roughly three kilometers of aerial cable were installed with expansion loops at every pole while the remaining length of aerial construction contain no loops. In this way, the effects of expansion (thermal and mechanical) on the cable can more effectively be analyzed.

The installation crew reported no difficulty in lashing the cable. On the average roughly 0.6 km of cable were installed daily. Somewhat more handling of the fibre optic cable was required than for co-axial cable. This resulted from the requirement to minimize the number of splices in the link.

6.4 Repeaters

Two repeaters were mounted aerially (strand mounted) in the link. Spacings were as follows:

1) Head-end to repeater #1 : 2.7km
2) Repeater #1 repeater #2 : 2.7km
3) Repeater #2 to hub : 2.4km

6.5 Cable Installation Conditions

The installation of the entire supertrunk took place under both summer and winter conditions. The problems encountered were no more complex than standard co-axial installations. Intersections were crossed, repeaters hung, lashing accomplished, all without damage caused to the fibre optic cable.

7.0 SPLICING AND CONNECTORIZATION

One of the more challenging aspects of fibre optics is providing suitable splicing and connectorization. Experience obtained during the BCN installation indicates that considerable work is required to develop and refine hardware and techniques to the point where splicing and connectorization of fibre optic cable can begin to compete with co-axial cable.

7.1 Splicing

There are a total of 10 fibre optic cable splices in the BCN link. Specifically there are 3 splices in the span from the head-end to repeater #1, 2 splices in the span from repeater #1 to repeater #2, and 5 splices in the span from repeater # 2 to the hub.

The process of performing a fibre to fibre splice has evolved quite rapidly over the past year. A year ago, splicing was achieved primarily by epoxying two fibre ends together in a hollow tube or v grove. The time required for the glue to set varied from one hour to several hours and, during this curing time, extreme care was required not to move the fibres. Typical attenuations of a splice performed using this technique varied substantially over a range of 1 to 3dB. Splicing losses were also fairly temperature dependent.

Recently, however, the development of a fusion splicer has lessened the problems associated with fibre to fibre splicing. Fusion splicing can guarantee repeatable splices with losses well under o.5dB, and are relatively insensitive to temperature changes. Fusion splicing equipment is however relatively sophisticated. A typical fusion splicer consists of an electric spark gap and electrodes, a mechanism for aligning fibres and a microscope for visual alignment. This type of equipment does not lend itself readily to field usage.

The major stumbling block in performing field splices of optical cable, however, does not stem from the fibre splicing, but rather from the preparation of the cable ends to expose the bare fibres. Exposing fibres requires the removal of the outer jacketing and moisture barrier, the removal of an inner polyethylene jacket, the replacement of buffer tubes and the fibre preparation. These processes require the talents of a skilled technician with considerable experience working in a reasonably protected environment. To date, field splicing has been accomplished in a plywood hut mounted on a scissor platform. Splicing from a ladder, tent, or bucket truck requires refinement of the techniques and equipment presently in use.

The time required per cable splice was two days for the first splice in the BCN installation and was streamlined to three hours for the last splice as the technicians became more familiar with the techniques.

7.2 Connectorization

The process of installing a fibre optic connector involves epoxying the fibre to a steel ferrule and then mounting this assembly in the body of the connector. The epoxying process requires a 12 - 24 hour curing time which has not been attempted in the field. Where field connectorization is desired, connectors have been preinstalled in the factory or fibre pigtails with pre-installed connectors have been spliced to cables

Connectorized cables have been installed to mate with input and output ports of repeater modules and terminal electro-optic modules.

Air gaps, if greater than 5 thousandth of an inch, can create transmission difficulties because of effects on bandwidth/pulse dispersion. This requires very close attention to tolerances during the connectorization process. Connector developments in the near future will reduce this problem by providing self alignment and self positioning of the fibre ends.

8.0 TESTS TO BE CONDUCTED DURING THE ONE YEAR TRIAL

Of major importance to the successful fruition of the fibre optic field trial is the documentation and analysis of results of the many technical and non-technical tests to be conducted during the one year of operation. The tests to be conducted are categorized into two main types: tests which measure the technical and economic aspects of the system and surveys which give a measure of how technical staff cope with the technology changeover and their reactions to the new technology.

8.1 System Tests

Following is a partial list of the system tests to be conducted:

1) Tests are being established to give technical comparisons between conventional co-axial trunks and fibre links for:
   a) Mean time before failure (MTBF).
   b) Mean time to repair (MTTR).
   c) Service and maintenance on a routine basis.
   d) System performance as a function of aging.
   e) System performance as a function of temperature.
   f) System performance as a function of other environmental aspects (rain, snow, ice, wind, lightning).

2) Test and documentation procedures are being devised to draw operating cost comparisons between conventional co-axial trunks and fibre links for the above categories.

3) Test procedures for the simulation of trunk links in excess of 7.8 km are being established. The tests give comparisons of technical performance of the optical fibre link for distances up to 48 km with and without digital retiming at every third repeater and with and without the effects of cascaded digital modems. (Loop through tests.)

4) Tests are being performed to evaluate all link specifications including:
   a) Signal to noise ratio.
   b) Intermodulation distortion.
   c) Bit error rate.
   d) Differential phase.
   e) Differential gain.

   These tests provide comparative technical performance data on both baseband and VSB modulation approaches.

5) Tests are being performed to evaluate optical hardware performance specifications such as:
   a) Received optical power.
   b) Optical fibre attenuation.
   c) Optical fibre dispersion.

6) Specific techniques are being investigated in the following areas:
   a) Field splicing.
   b) Connector attachment.
   c) Location of a broken fibre.

d) Signal identification on a fibre.

e) Repeater module replacement.

f) Light source/receiver service and replacement.

g) Status monitoring.

h) Cable lashing.

i) Powering, regulation and surge protection.

j) Bi-directional signal transmission.

8.2 Personnel Acceptance and Adaptation Tests

Surveys are being designed to maximize information retrieval in the area of personnel acceptance and adaptation to the technology changeover. The surveys are intended to cover all aspects of optical fibre, CATV design, and operation. Specifically, the areas of interest are:

1) System design for the CATV Engineer.
2) System implementation for the Engineer/technologist.
3) System installation for the field technician.
4) System operation (maintenance and service) for the service technician.

9.0 CONCLUSION

The BCN installation is the result of a concerted co-operative effort of the Canadian Department of Communications, the Cable industry and a Canadian manufacturing company. It marks the beginning of a new era in telecommunications. The degree to which Fibre Optics will find its way into the cable network is in part established by the creativity and commitment demonstrated by government and industry. The BCN link may appear to represent a modest step forward in the technology of fibre optics when compared to more "blue sky", revolutionary installations which capture the attention of many advocates of the 'wired city' concept. However, the BCN installation represents a sound engineering systems approach to realizing a graceful evolution of fibre optic and digital technology into the CATV plant. The BCN project marks the beginning of the quiet revolution.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the valuable technical discussions by their colleagues at Harris ESD. Whitworth W. Cotten, Paul Casper and Dr. Richard Patisaul; at Canstar Communications, George Reesor and Tom Fan; and at Cablesystems Engineering, Ed Jarmain and Nick Hamilton-Piercy; and to the Canadian Cable industry consortium of BCN Fibre Optic Inc. Membership of the BCN consortium consists of Canadian Cablesystems Limited; Rogers Cable TV Ltd.; Premier Cablevision Ltd.; Western Cablevision; National Cablevision Limitee; Cable TV Ltd.; and Canada Wire and Cable Co. Ltd.

We would further like to acknowledge the technical and financial support given to this project by the Canadian Federal Department of Communications in Ottawa.

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APPENDIX I

SPECIFICATION: FIBRE OPTIC CABLE FOR ON-POLE INSTALLATION

Number of channels (fibres)	8
All channels of equal length per unit cable length	
Intentional torsion on fibres in cable not acceptable	
Cable attenuation (at least 7 of 8 channels)	6dB/km*
Cable bandwidth (dispersion)	600MHz km**
Pre-cabled fibre pull strength	0.25kg***
Recommended fibre tensile loading in cable	0.10kg
Fibre available in lengths of 1100 meters	
Fibre outside diameter	0.125mm
Fibre outside diameter with lacquer coating	0.132mm***
Pull strength of cable (self supporting)	2900kg
(supported)	230kg
Strength member preferably non-metallic (e.g. KEVLAR)	

Temperature Effects: Change in attenuation to be less than $\pm$1dB over the following range:

Maximum temperature (with direct solar radiation)	50°C
Minimum temperature (no solar radiation)	-40°C

Driving rain with 80km/hr wind	30mm/hr
Freezing rain at 80km/hr wind	30mm radial ice
Maximum wind at 10m above ground	150km/hr

Outer jacket material: PE, PU or neoprene
Cable configuration, other than above, optional
Cable outside diameter (minor axis) should be less than 20mm

* Attenuation: measurements are normalized to one kilometer lengths and are specified at a wavelength of 820 nanometers. Measurements are carried out with a standard input radiation launch numerical aperture of 0.1. Measurements are made at room temperature.

** Bandwidth: The bandwidth of optical waveguides is derived from pulse-broadening measurements normalized to one kilometer lengths. A sub-nanosecond pulse of light (at 900nm) from a solid state LOC injection laser is launched into the waveguide. The laser spectral width is approximately 3.8nm (FWHM). Input launch conditions excite all propagating modes. The output pulse is monitored and represented in the frequency domain using Fourier transform methods. Bandwidth is specified at the optical power -3dB point.

*** As supplied by fibre manufacturers.

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Donald G. Monteith was born in Montreal, Canada, on April 29th, 1952. He received his Bachelor of Engineering honours degree in electrical engineering from McGill University, Montreal in 1973.

While in Montreal, he also undertook post-graduate work at McGill University in the area of video image enhancement and specialized colour graphics hardware design. He received his Master of Engineering degree in 1975.

In 1976 he accepted a position with Cablesystems Engineering, a division of Canadian Cablesystems Limited, where his primary functions were in the area of the research and development of broadband telecommunications for CATV applications.

In 1977, he was appointed Senior Project Engineer, Fibre Optic Systems, for Cablesystems Engineering.

Don is a Registered Professional Engineer and a member of the Association of Professional Engineers of Ontario. He is also the current chairman of the Fibre Optics Technical Sub-Committee of the Canadian Cable Television Association and in this capacity has authored and coauthored several papers on Fibre Optics for the CCTA. Don is also a member of the IEEE and a working member of a Canadian Sub-Committee of the International Electrotechnical Commission.

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Joe was previously with CAE Electronics as an engineering and project manager responsible for projects related to flight simulation.

Joe received his Bachelor of Applied Science in Electrical Engineering from the University of Toronto in 1958 and his Master of Business Administration from the University of Toronto in 1978. He is a member of the Association of Professional Engineers of Ontario, Institute of Electrical, Electronic Engineers, the Engineering Institute of Canada and the Project Management Institute.

INSTALLATION AND PERFORMANCE OF A FIBEROPTIC VIDEO SYSTEM AT VIACOM

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ABSTRACT

This paper describes the Fiberoptic Video System installed by Valtec Corporation at Viacom's Suffolk County Cablevision in Islip, Long Island, N.Y. The system is designed to carry a single studio quality video and audio signal over an 8800 foot long aerial fiberoptic cable. The design of the terminal equipment, and 3-fiber aerial cable is discussed. System performance is cited.

INTRODUCTION

A turnkey fiberoptic transmission system connecting the Local Program Origination Studio with the Head End was installed by Valtec Corporation at Viacom's Suffolk County Cable-Vision in Islip, Long Island.

The system was designed to transmit a single video and audio channel over a distance of 2.7 km(8800 feet) without the use of line amplifiers. The terminal equipment was installed in the working environment of a television studio at one end, and head end at the other. A three fiber aerial cable was installed by Viacom's installation crew under the supervision of technical personnel from Valtec. Although present system requirements called for only one fiber transmission, a three fiber cable was installed to facilitate future expansion of services offered by Viacom.

The optical fiber, aerial cable, and the terminal equipment including the Light Emitting Diode were designed and manufactured by Valtec Corporation. The cable and system installation took place in early December, 1978.

TERMINAL EQUIPMENT

The terminal equipment was designed to interface between the electrical signals and the fiberoptic cable. A block diagram of the terminal equipment arrangement is shown in Fig. 1. At the transmitter end, the baseband audio signal is modulated onto an RF carrier, and combined with the composite video signal. Together, these frequency division multiplexed signals are converted into equivalent light intensity modulated signals by the combination of the LED, and the driver circuit.

The light is coupled into the fiber pigtail which is connected to the fiberoptic cable via a demountable optical connector. At the receiver end, the light is coupled from the cable into a detector pigtail via an optical connector. The detected light levels are transformed into photocurrent which is amplified by the receiver circuit. The audio RF carrier is filtered from the received signal by the audio demodulator which converts the RF into the baseband audio.

VIDEO TRANSMITTER

A block diagram of the video transmitter is shown in Fig. 2a. The video and RF audio are summed by a transimpedance amplifier which feeds the predistortion circuit. The predistortion circuit was designed to compensate for the nonlinearities of the LED, and, therefore, improve the differential gain and phase distortions of the transmission system. The predistortion circuit feeds a voltage to current converter which in turn powers the Light Emitting Diode.

Valtec's own IRE-160F LED was employed in the transmitter circuit. The entire video transmitter circuit, including the LED and the optical connector, was assembled on a single plug-in type printed circuit board. The individual transmitter parameters are listed below.

Light power coupled into the fiber	26 μW
Modulation index	90%

Frequency response	1 Hz to 35 MHz
Differential gain	< 2%
Differential phase	< 2.5°
Power Supply	± 15V
Power Consumption	< 2.5 W
Input Impedance	75 Ω (DC to 35 MHz)
Input Signal Level	1-10 Vp-p

AUDIO MODULATOR

A unique modulation scheme was employed in the audio modulator circuit. This technique, labeled the period modulation scheme, nears the performance of an FM system, but retains the simplicity of AM. A block diagram of the audio modulator is shown in Fig. 2b.

The baseband audio, 600 Ω balanced or 5000 Ω unbalanced, feeds the input buffer and preemphasis filter. The signal then enters the low frequency period modulator which outputs a TTL signal whose period is proportional to the input voltage. This signal in turn AM modulates a crystal controlled RF carrier. The carrier, after passing through a band pass filter, feeds the video transmitter. Advantages of the modulation scheme employed here over conventional schemes are frequency stability, ability to transmit drift free dc information, and ability to transmit data from DC to 250 kb/sec. The modulator specifications are listed below.

Input impedance	600/5000 Ω
Input signal level for 100% modulation	4 Vp-p
RF carrier	15 MHz
Carrier amplitude	15 db below color subcarrier
Preemphasis time constant	75 μsec
Frequency deviation	150 KHz total
Power consumption	< 2.5 W
Power supplies	± 15 V

VIDEO RECEIVER

A block diagram of the receiver circuit is shown in Fig. 3a. The light emerging from the optical cable is guided into the PIN photodetector via a fiber pigtail which interfaces with the cable through an optical connector. A Field Effect Transistor(FET) preamplifier is used in order to maximize the signal to noise ratio of the video signal. The AGC amplifier keys on the horizontal sync pulses, and provides a constant RS-170 compatible video output. The signal from the AGC amplifier flows to the line driver, and the dc restoration circuit which clamps the blanking level at OV dc. Receiver parameters are listed below.

Signal to noise ratio at 0.8 μW light signal power	52.4 db CCIR weighted
Frequency response	3 dB at 7 Hz and 18 MHz
Dynamic range	10 dB optical 20 dB electrical
Power supplies	+ 15 - 15

AUDIO DEMODULATOR

The RF carrier is filtered from the receiver output by the band pass filter as shown in Fig. 3b. The signal is envelope detected, and fed into the period demodulator circuit which yields a baseband audio signal at the output. The deemphasis and output buffering are accomplished in the last circuit stage. The demodulator performance is given below.

Audio frequency response	20 Hz to 18 KHz
Signal to noise ratio at 100% modulation	50 dB, 18 KHz bandwidth
T.H.D.	< 0.1%
Output Signal	4 Vp-p at 100% modulation
Output Impedence	600 Ω or 5000 Ω
Power Supplies	± 15V

The system components(the video transmitter, the audio modulator, video receiver, and the audio demodulator) were manufactured on individual printed circuit cards, and mounted in a 19" rack mountable chassis with individual power supply modules.

THE CABLE

The Viacom system required that the 2.7 km cable be aerial, with exposure to the elements, and temperature extremes of from -40°C to +65°C. The cable had to have an end-to-end loss, including splices and connectors, of less than 17 dB in order to meet the system requirement for the signal to noise ratio. A loose tube cable design was chosen for this application. In this design, each fiber was put into a polypropylene 2.5 mm O.D. tube. Contra-helical layers of Kevlar ® were overlayed to act as strengthening members. A thin color coded jacket of urathane formed the final extrusion on each of these sub-members of the cable. Each sub-member exhibited a short gauge length strength of 270 kg (600 lbs.).

The three km lengths of sub-channels were stranded and bound with polypropylene tape; with Mylar ® wrapped over them to form a heat barrier. During stranding, the 3 km length of cable was cut in half to facilitate handling. An additional contra-helically laid Kevlar ® belt with a urathane jacket was applied to each of the 1.5 km lengths of cable forming an O.D. of 12.4 mm(.50").

To assure the moisture resistance of the cable, a corrugated steel belt was applied around the cable. The steel belt was then jacketed with a 1.25 mm(.050") polyethylene jacket. The final cable weight was 223 kg/km(492 lbs.).

Installation of the first length of cable took place in early December of 1978. The installation started at the head end. The first pull section to a pole on Willson Blvd. was 200' long. At that point, the cable negotiated an 80° bend, and continued over cable blocks down Willson Blvd. The cable was pulled by attaching the cable through a short pulling line to the bucket of a service truck. Reasonable effort was made to maintain the pulling axis close to the messenger during the pulling operation. Frequent stops were made during pulling to thread the cable through numerous trees that dotted the roadside, and for routing the cable to the field side of many of the poles. The first section pulled was 1.25 km(4100') long. It took nearly a day to complete, and an additional day to lash. The second length of cable was installed in the same manner with the starting point at the studio on Brightside Avenue, and the cable pulled down Willson Blvd. to meet the end of the first cable.

It should be noted that the installation crew had no prior training on the installation of fiber cable, and as a result, treated this cable as a conventional coaxial cable.

Splicing was accomplished in less than favorable weather with temperatures in the teens, and 20 to 30 MPH winds. Despite the fact that a heated bucket was provided for the Valtec engineer who spliced the cable, the conditions for splicing small 5 mil fibers were barely adequate due to the wind and cold. Nevertheless, all splices were successful on the first attempt.

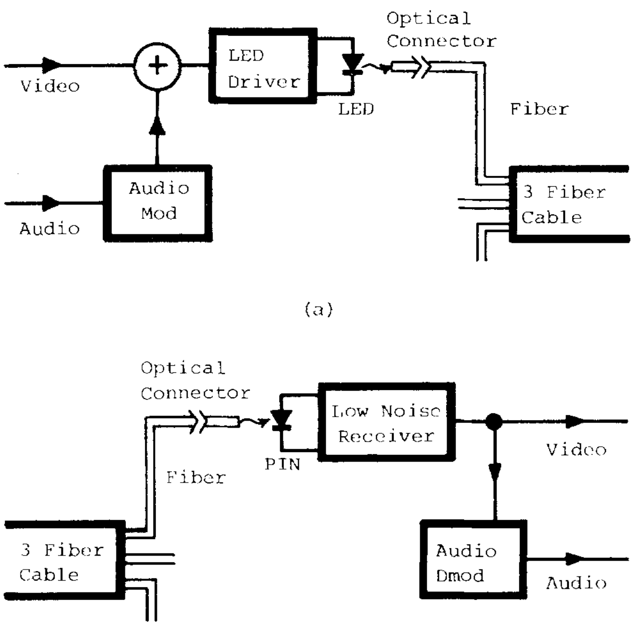
A conventional cast iron telephone splice case was used. Half of the case was clamped to the messenger. To the lower edge, an aluminum base was bolted to form a platform on which to work. The front lip of this platform was rested on the edge of the bucket for support. The platform accommodated the microscope, splices, epoxy, and other tools required to perform the splice. The splicing was accomplished using Thomas & Betts armored splices. This splice requires that the cable be prepared by removing the outer jacket of the cable sub-members, and cutting the Kevlar ® to length(as well as the polypropylene tube). The fibers are then cleaved and inserted into the V groove splice, and aligned under a microscope. A heater in the microscope base shrinks tubing around the fibers, and holds them in place. The Kevlar ® is crimped to the splice, and clear epoxy is inserted through a viewing port to act as an optical coupling agent, and to bond the fibers to the splice. Shrink tubing is put over the entire assembly, and the splice becomes an integral part of the sub cable. After splicing was completed, the splice case was closed, and sealed with sealing tape. The fiber and cable parameters are listed below.

Cable length	2.7 km(8800')
Weight	492 lbs/km (223 kg)
Strength	> 400 lbs (gauge length - 1/2 km)
Temperature performance	< 1 dB/km -50°C to +85°C
Number of fibers	3
Fiber attenuation including splice and two connectors	13 dB(2.7 km length)
Fiber bandwidth	> 200 MHZ-km

SUMMARY

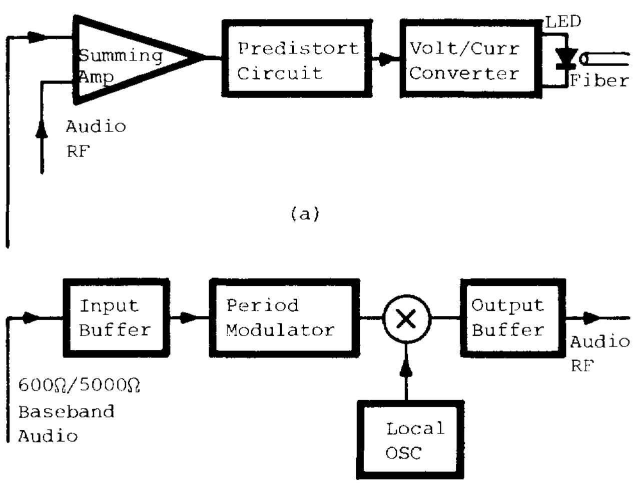
A turnkey high quality video transmission system was successfully installed in a working CATV environment. The system currently carries a single video and audio channel over a distance of 8800' without the use of line amplifiers. With the advent of higher opto-electronic technology, the system capacity can be expanded to at least 30 TV channels.

The authors wish to thank their colleagues at Valtec Corporation who have been involved in manufacturing and installion of all system components.



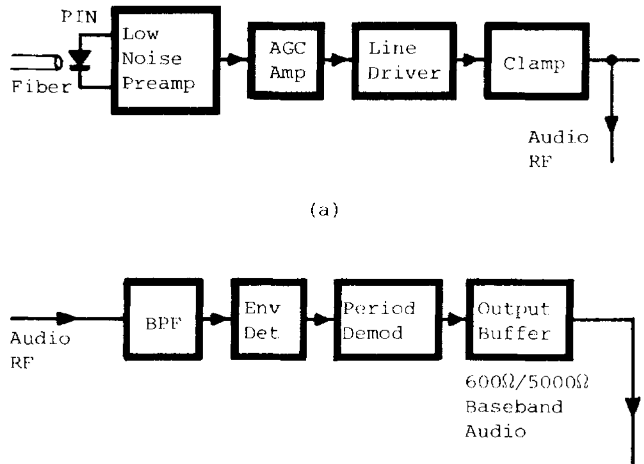
(b)

Fig. 1. Fiber optic interface circuits. (a) Studio. (b) Head end.



(b)

Fig. 2. (a) Video transmitter. (b) Audio Modulator.



(b)

Fig. 3. (a) Video receiver. (b) Audio Demodulator.

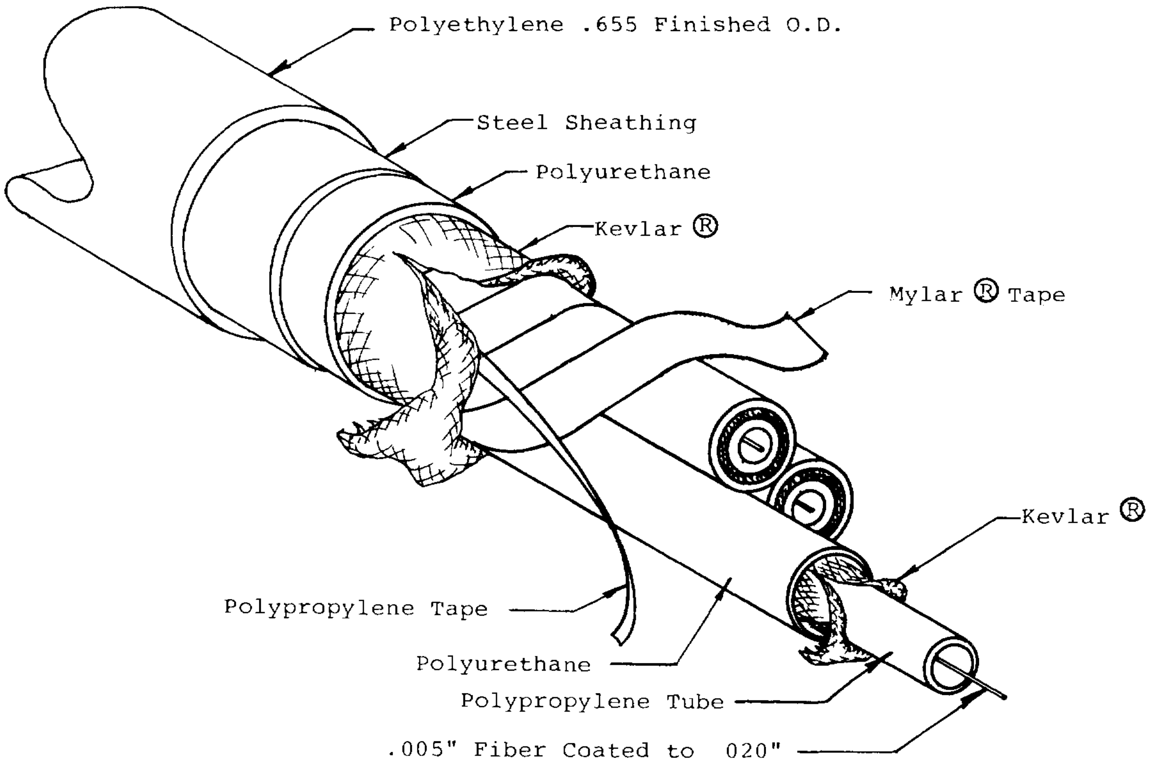


Fig. 4. Cross sectional view of the three fiber cable.

MASTER FILE SEARCH (MFS)

- An Analytical Tool For The Spectrum Manager

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Abstract

The Spectrum Survey and Analysis Branch of the Spectrum Allocation Division of the Office of Chief Engineer within the Federal Communications Commission (FCC) has developed a computerized retrieval system for license information. This paper discusses this FORTRAN-based system which runs on the FCC's UNIVAC 1106 computer. The Master File Search (MFS) system contains over 1.2 million records covering all non-Government frequency assignments except for citizens and amateur licenses. The records contain technical information such as frequency, power, emission type(s), antenna height, station coordinates, etc., as well as some non-technical information such as call sign, service code, class code, etc. The paper, by way of sample queries, demonstrates the utility of the system as an analytical tool helping the spectrum manager solve spectrum allocation problems. The paper also discusses the limitations of the system and examines some of the future enhancements which will be made to the MFS.

Introduction

Most people are familiar with the automated reservation systems utilized by travel agencies, airline ticket personnel and hotels. Imagine the delays and confusion if such a system had not been developed, especially with today's heavy volume of air travel. Some planes would be seriously overbooked, travel agents could not give up-to-the minute flight information, and in general, the entire commercial aviation industry would be unmanageable. Fortunately such a system does exist which prevents gross overbooking and provides timely occupancy information to consumers and managers in the travel industry.

What does the airline and hotel businesses have to do with communications? The same tools which these businesses use to manage their limited resources can be applied to the managing of the electromagnetic spectrum. Just as an airplane or hotel can hold only so many people before a congestion problem develops, so too a radio channel can become overbooked (overassigned) to the point of becoming virtually useless as a means of communications. To gain a handle on the current state of occupancy of various portions of the spectrum an automated system of retrieving license information is needed. This is where the Master File Search system can help.

The Master File Search (MFS) system was developed to provide the spectrum manager with statistics on how various channels are being assigned. It should be noted that unlike an airplane or hotel which has a predetermined upper limit on its capacity, a communications channel may show a large number of assignments, possibly indicating an ineffective means of communication, but due to geographic spacing and/or time-sharing the channel is indeed a useful means of communication. While the MFS system cannot now determine if a channel is ineffective as a communications link, it provides the capability of making relative channel assignment comparisons.

The MFS System

In recent years, information such as how many transmitters are licensed within a particular frequency range could only be obtained by counting assignments on reams of computer output. If a finer distinction were needed such as how are these transmitters distributed among the top twenty-five (25) Standard Metropolitan Statistical Areas (SMSA), only a small sample could be obtained. This manner of data gathering was not adequate for the types of spectrum analysis work which is needed for making decisions for new allocations. The use of the digital computer greatly alleviated the manual search of the license records, but because of the size of the file (at one time this file was spread across forty-five (45) reels of magnetic tape) processing was still cumbersome. Presently, the FCC records show close to 1.2 million frequencies in use. Nominally twenty-six (26) different pieces of information, such as licensee name, address, call sign, etc. are maintained for each of these frequencies. Using this conservative figure over thirty-one million pieces of information are stored in the FCC list of frequency assignments. This list is commonly referred to as the master frequency file or the MFF. Ideally, one would like to have all this information available to the spectrum manager through an on-line (disk) automated information retrieval system. However, due to equipment limitations the MFS system contains a subset of the information stored in the MFF. The data elements which are included in the MFS system are enumerated in Table 1. This table represents those elements which are readily available from the MFF and which appear to be of most value to the spectrum manager.

To access the data in the MFS system, a series of FORTRAN computer programs were written which provide a query capability. These programs may be run in either the time-sharing (demand) mode or the batch mode. In the time-sharing mode, the user is guided through the program through a series of menu type selections. Queries can be made on three (3) basic parameters. These parameters are frequency, geographic area and data. Under the frequency parameter, the data in the MFS system can be extracted on discrete frequencies, such as 450.1 megahertz (MHz) or 10.2 gigahertz (GHz), up to three hundred (300) individual frequencies, or on frequency bands, such as 450.0 to 470.0 MHZ or 10.2 to 10.3 GHz, up to one hundred fifty (150) bands. Also provisions have been made for selecting frequencies based on service (e.g. base or mobile) and/or class (e.g. business or cable television) designations. Under the area specification there are several ways in which to describe a geographic area. The four (4) coordinate points of a rectangle may be specified, a circle of center, x, y, (x, y are the coordinate values) and radius, r, (r is the number of miles around the center) may be described, areas may be chosen by state, state and county pairs, SMSA code and lastly, above or below the line used for Canadian frequency coordination (Line A). Under the date specification parameter license information may be selected by authorization or expiration date of the license. These three searching parameters provide a broad range of criteria on which to retrieve frequency assignment information.

How the MFS System Can Be Used as a Tool by the Spectrum Manager

Rather than give a tutorial on how one would use the MFS system, the remainder of this paper will look at queries which have been run to demonstrate the utility of this system as a spectrum analysis tool. For detailed information concerning using the MFS system the reader may consult reference 1 at the end of the paper.

Since much of the freauency spectrum is used in one way or another, most requests for new frequency allocations translate into requests for reallocation of existing frequency bands. Reallocation of the frequency spectrum leaves the spectrum manager with the following choices:

1) deny the reallocation request;
2) try to accommodate the reallocation request through sharing of the frequency spectrum with existing users;
3) accommodate the reallocation request by moving the current users out of the requested band.

Before the spectrum manager can decide on which course of action to take, an analysis of the particular request must be performed. Usually a request such as this comes to the FCC in a petition for rule making which is a formal statement of the intended use of the frequency spectrum. It is the responsibility of the spectrum manager to review these petitions making certain that the intended use is in the public interest. The queries which follow are examples which the spectrum manager might perform during the course of an analysis.

Sample Queries

The following queries were done solely for purposes of demonstration. Each query is designed to point out a specific feature of the MFS system, however, they are typical of the types of queries which have been made since the system became operational. Sample 1 shows a listing of stations which operate in the 12.75 - 12.75 GHz band in the New York City Standard Metropolitan Statistical Area. Sample 2 shows a plot of stations licensed between January 1, 1975 and December 12, 1975 for the band 12.7 - 12.95 GHz and located within the continental United States. Sample 3 is another way of representing this same information only this time in a tabular form. Sample 4 shows a continental U.S. plot of the stations in the 12.7 - 12.95 GHz band authorized between January 1, 1975 and March 31, 1979. Comparing this plot with the one shown in Sample 2 reveals a marked increase in the number of stations in this short period of time. The asterisks (*) on the later plot signifies those areas with more than twenty-five (25) stations. These areas appear to be major cities such as New York, Los Angeles and Chicago.

Sample 1

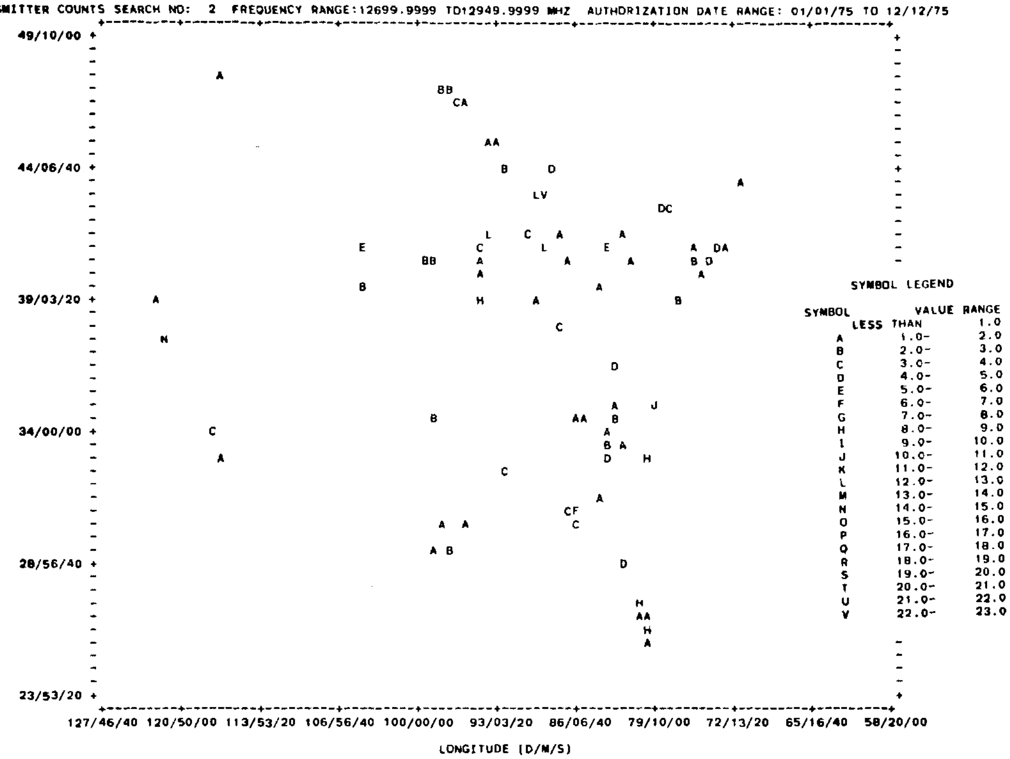
```
INTERNATIONAL & OPERATIONS DIVISION PRINT FORMAT  -  SEARCH:    1

RECORD #   FREQUENCY  SVC    CALL    T ST  XMTR COUNTY    FID    ATD     EXD  CLASS
 LATITUDE     LONGITUDE     EMISSION(S)         POWER   GR EL   ANT  UNITS  REC ID

       1  M12754.5000-  TR WDC400    L NY ROCKLAND      053178 053178 050183 CAR
41-06-50 N 074-04-40 W M  5.75A5C            W  5.000 X    0    150     0 1205480
       2  M12754.5000-  TR WDC400    L NY ROCKLAND      053178 053178 050183 CAR
41-06-50 N 074-04-40 W K250.00F3             W  5.000 X    0    150     0 1205481
       3  M12759.7001-  TR WOL62     L NY NEW YORK      062973 062973 020176
00-00-00 N 000-00-00 W                       K   .000 I    0      0     0 1205515
       4  M12766.5000-  TR WDC400    L NY ROCKLAND      053178 053178 050183 CAR
41-06-50 N 074-04-40 W M  5.75A5C            W  5.000 X    0    150     0 1205588
       5  M12766.5000-  TR WDC400    L NY ROCKLAND      053178 053178 050183 CAR
41-06-50 N 074-04-40 W K250.00F3             W  5.000 X    0    150     0 1205589
       6  M12775.0000-  TR WJC47     L NJ BERGEN        112376 112376 020181 CAR
40-57-39 N 073-55-23 W M 24.90F9              U250.000 X    0      0     0 1205687
       7  M12775.0000-  TR WJC51     L NJ BERGEN        121676 121676 020181 CAR
40-57-39 N 073-55-23 W M 24.90F9              U250.000 X    0    416     0 1205688
       8  M12775.0000-  TR WIC61     L NY NASSAU        113076 113076 020181 CAR
40-41-08 N 073-36-37 W M 25.00F9             W  1.000 X    0      0     0 1205694
       9  M12775.0000-  TR WIC61     L NY NASSAU        101277 101277 020181 CAR
40-41-08 N 073-36-37 W M 25.00F9             W  1.000 X    0    333     0 1205695
      10  M12777.7001-  TR WOL62     L NY NEW YORK      062973 062973 020176 CAR
40-47-34 N 073-58-15 W M  5.75A5C             U100.000 I    0      0     0 1205769
      11  M12777.7001-  TR WOL62     L NY NEW YORK      062973 062973 020176 CAR
40-47-34 N 073-58-15 W K250.00F3              U100.000 I    0      0     0 1205770
      12  M12778.5000-  TR WDC400    L NY ROCKLAND      053178 053178 050183 CAR
41-06-50 N 074-04-40 W M  5.75A5C            W  5.000 X    0    150     0 1205779
      13  M12778.5000-  TR WDC400    L NY ROCKLAND      053178 053178 050183 CAR
41-06-50 N 074-04-40 W K250.00F3             W  5.000 X    0    150     0 1205780
      14  M12800.0001-  TR WJV31     L NY NASSAU        021473 021473 020176 CAR
40-42-58 N 073-36-09 W M 25.00F9              U615.000 I    0      0     0 1205951
      15  M12820.5000-  TR WHW60     L NY NEW YORK      032175 032175 020178 CAR
40-50-52 N 073-56-08 W M  5.75A5C            W  1.000 X    0      0     0 1206146
      16  M12820.5000-  TR WHW60     L NY NEW YORK      032175 032175 020178 CAR
40-50-52 N 073-56-08 W K250.00F3             W  1.000 X    0      0     0 1206147
      17  M12825.0000-  TR WDW70     L NY NEW YORK      113076 113076 020181 CAR
40-46-08 N 073-58-55 W M 25.00F9             W  1.000 X    0      0     0 1206261
      18  M12868.5000-  TR WDC400    L NY ROCKLAND      053178 053178 050183 CAR
41-06-50 N 074-04-40 W M  5.75A5C            W  5.000 X    0    150     0 1206658
      19  M12868.5000-  TR WDC400    L NY ROCKLAND      053178 053178 050183 CAR
41-06-50 N 074-04-40 W K250.00F3             W  5.000 X    0    150     0 1206659
      20  M12875.0000-  TR WIC61     L NY NASSAU        113076 113076 020181 CAR
40-41-08 N 073-36-37 W M 25.00F9             W  1.000 X    0      0     0 1206738
      21  M12875.0000-  TR WIC61     L NY NASSAU        101277 101277 020181 CAR
40-41-08 N 073-36-37 W M 25.00F9             W  1.000 X    0    333     0 1206739
      22  M12875.0000-  TR WDW70     L NY NEW YORK      113076 113076 020181 CAR
40-46-08 N 073-58-55 W M 25.00F9             W  1.000 X    0      0     0 1206740
      23  M12879.7001-  TR WOL62     L NY NEW YORK      062973 062973 020176 CAR
40-47-34 N 073-58-15 W M  5.75A5C             U100.000 I    0      0     0 1206814
      24  M12879.7001-  TR WOL62     L NY NEW YORK      062973 062973 020176 CAR
40-47-34 N 073-58-15 W K250.00F3              U100.000 I    0      0     0 1206815
      25  M12886.5000-  TR WDC400    L NY ROCKLAND      053178 053178 050183 CAR
41-06-50 N 074-04-40 W M  5.75A5C            W  5.000 X    0    150     0 1206842
```

SAMPLE 2

RANSMITTER COUNTS SEARCH NO: 2 FREQUENCY RANGE:12699.9999 TO12949.9999 MHZ AUTHORIZATION DATE RANGE: 01/01/75 TO 12/12/75



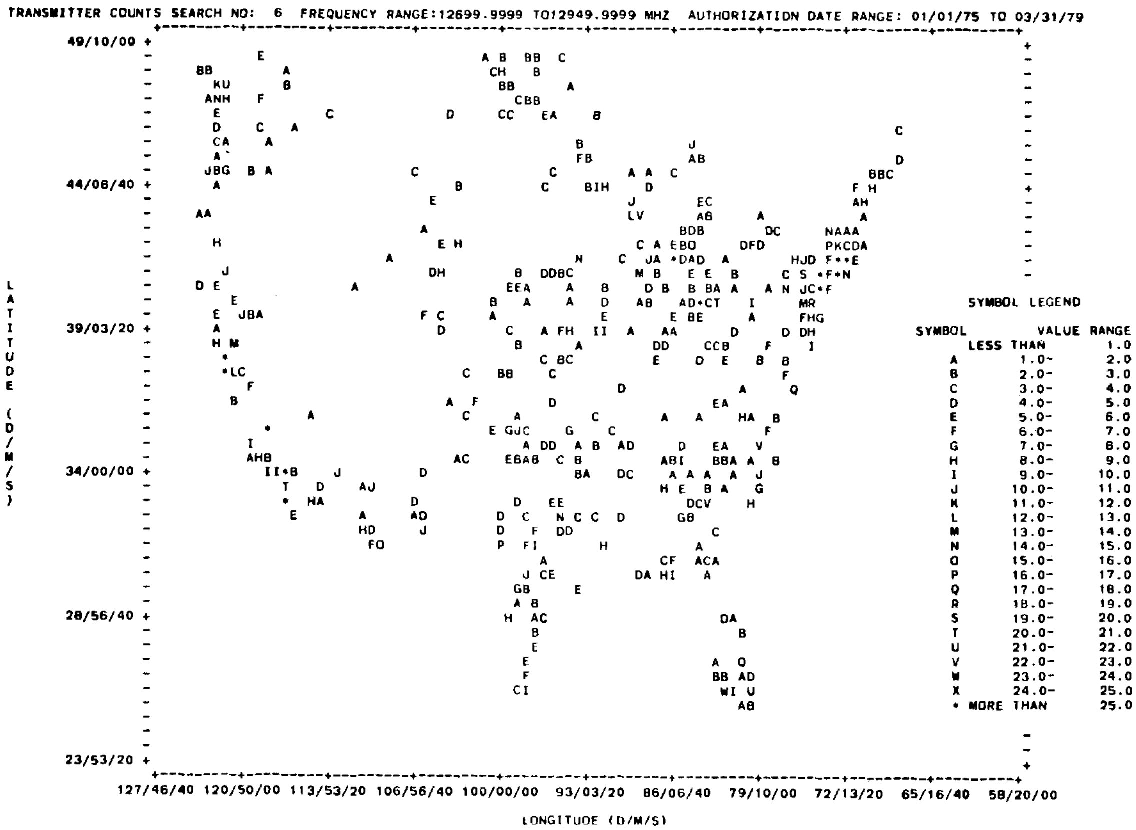
SAMPLE 3

TRANSMITTER COUNTS SEARCH NO: 2 FREQUENCY RANGE:12699.9999 TO12949.9999 MHZ AUTHORIZATION DATE RANGE: 01/01/75 TO 12/12/75

LONGITUDE (D/M/S)

	127 48 40	125 0 0	122 13 20	119 26 40	116 40 0	113 53 20	111 6 40	108 20 0	105 33 20	102 46 40	100 0 0	97 13 20	94 26 40	91 40 0	88 53 20	86 6 40	83 20 0	80 33 20	77 46 40	75 0 0	72 13 20	69 26 40	66 40 0	63 53 20	61 6 40	58 20 0	TOTALS
49/10/00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
48/09/20	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1
47/08/40	0	0	0	0	0	0	0	0	0	0	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0		8
46/08/00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
45/07/20	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0		2
44/06/40	0	0	0	0	0	0	0	0	0	0	0	0	2	0	4	0	0	0	0	0	1	0	0	0	0		7
43/06/00	0	0	0	0	0	0	0	0	0	0	0	0	0	12	22	0	0	4	3	0	0	0	0	0	0		41
42/05/20	0	0	0	0	0	0	0	0	0	0	0	0	12	3	1	0	1	0	0	0	0	0	0	0	0		17
41/04/40	0	0	0	0	0	0	0	0	5	0	4	0	4	0	13	0	6	0	3	9	0	0	0	0	0		44
40/04/00	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0		5
39/03/20	0	1	0	0	0	0	0	0	0	0	0	0	8	1	0	0	0	0	2	0	0	0	0	0	0		12
38/02/40	0	0	14	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0		17
37/02/00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0		4
36/01/20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
35/00/40	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	3	10	0	0	0	0	0	0	0		17
34/00/00	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0		7
32/59/20	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	4	8	0	0	0	0	0	0	0		16
31/58/40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0		1
30/58/00	0	0	0	0	0	0	0	0	0	0	1	1	0	0	3	9	0	0	0	0	0	0	0	0	0		14
29/57/20	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0		3
28/56/40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0		4
27/56/00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0		8
26/55/20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0		10
25/54/40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0		1
24/54/00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
23/53/20																											
TOTALS	0	1	14	5	0	0	0	0	7	0	10	9	32	16	46	13	26	41	8	10	1	0	0	0	0		239

SAMPLE 4



The Next Generation of the MFS System

As experience is gained with the MFS system, suggestions have been made regarding improvements for the system. Some of these improvements are in the area of making the MFS system more "human" in detecting and, where possible, correcting errors. Other suggestions have been directed toward pointing out some of the limitations of the system. These suggestions are welcome and some have been already implemented.

The MFS system was created in a modular fashion. Because of this building block approach it is amenable to change without massive redesign or recoding. Some of the improvements which will soon be available through the system is the ability to query information found in the FCC Table of Frequency Allocations. The Table of Frequency Allocations currently exists as a separate query program (reference 2) and its incorporation into the MFS system will tie allocation and assignment information together. Another improvement which will be forthcoming is the ability to query the license file on service and class codes. This summer a project will be started to include the date when a station was first licensed to operate. This information will give the spectrum manager the ability to develop time-series analyses and to project future loading characteristics of various portions of the frequency spectrum. Some of the long range goals include the addition of license information from sources other than the non-Government sector such as Government assignments, Canadian and Mexican stations.

Data Integrity - A Caveat

There are several problems regarding the integrity of the data stored on the MFS system which should be noted. Records which reflect mobile assignments do not in general have coordinate information. Because of this situation, queries using a geographic description such as a rectangle or a circle will not retrieve these records. There is a problem with some records appearing more than once on the file. This condition arises when an update procedure is in error causing duplicate records to be left on the file. Also, assignments such as television broadcast stations may appear more than once because of the convention of storing the two powers (visual and aural) in two separate records. In conclusion, there is a problem with keystroking errors which of course means lost information. In our work we have been able to detect most errors, but can not correct them outside of going back to the source document which is the paper license. An analysis of the error problem is described in reference 3.

TABLE 1

SPECTRUM ALLOCATION DIVISION
COMPRESSED MASTER FREQUENCY FILE

RECORD LAYOUT

Item No.	Identification	Start Position (WORD/BITS)	Item Length (Bits)
1	Record ID	1/0	36
2	Frequency(10 Hz)	2/0	36
3	Call Sign (coded)	3/0	36
4	Latitude (USEC)	4/0	20
5	Original Issue Date (YMD)	4/20	16
6	Mobile units	5/0	14
7	Longitude (USEC)	5/14	21
8	RESERVED	5/35	1
9	Renewal/Issue Date (YMD)	6/0	16
10	Expiration Date (YMD)	6/16	16
11	Alaskan Zone Frequency	6/32	1
12	Band Edge Frequency	6/33	1
13	Special Call Sign	6/34	1
14	RESERVED	6/35	1
15	Power (uW)	7/0	14
16	Ground elevation (feet)	7/14	15
17	Service (coded)	7/29	7
18	Emission #1 (coded)	8/0	24
19	Antenna height (feet)	8/24	12
20	Emission #2 (coded)	9/0	24
21	Type of power (coded)	9/24	3
22	Class (coded)	9/27	8
23	RESERVED	9/35	1
24	State (coded)	10/0	7
25	County (coded)	10/7	12
26	Number of other emissions	10/19	3
27	Type of authorization	10/22	4
28	County overflow (HOB, coded)	10/26	2
29	RESERVED	10/28	2
30	Search Index (0 value)	10/30	6

Abbreviations used above:

10 Hz - value stored in 10 Hertz

coded - stored structure of the item is coded by some algorithm

USEC - value is stored in total seconds with a bit indicating the direction of the coordinate point, i.e. North, East, South, or West.

YMD - value is stored; year, month, day

feet - value stored in feet

uW - value stored in microwatts

HOB - high-order bits

REFERENCES

1. Tremper, Phillip G. and Cesaitis, Joseph V. Master File Search System MFS Users Guide. Washington, D.C.: Federal Communications Commission, FCC-OCE-SA-79-02

2. Cesaitis, Joseph V. An Automated Retrieval System for Frequency Allocation Information. Washington, D.C.: Federal Communications Commission, FCC-OCE-SA-79-01

3. Tremper, Phillip G., Survey of the non-Government Master Frequency File. Washington, D.C.: Federal Communications Commission, FCC-OCE-SA-78-01

MICROPROCESSOR CONTROL FOR CATV TEST INSTRUMENTS

SYD FLUCK AND MARV MILLHOLLAND

WAVETEK INDIANA INC.

ABSTRACT

The unique measurement requirements of our industry have, in the past, been served by general purpose test instruments requiring a high degree of operator interface and understanding. As technology advances, the microprocessor will smooth this interface and improve operating efficiency. Microprocessors allow us to configure an instrument to handle our unique requirements. Application of the microprocessor in the design of a new simultaneous-sweep system will emphasize the areas of improvement made possible by the use of this versatile component. The use of microprocessor control allows us to get the most useful information for the time spent testing. Areas where the microprocessor has had considerable influence are: minimization of the number and types of controls, digital storage of sweep response, communication between instruments, and post processing of response data. These areas will be discussed in some detail, along with the idea of upward expandability.

INTRODUCTION

Test instruments must provide the operator with some useful source of stimulus, the means to analyze an output from a device under test, or a combination of the two. In the past, high-frequency test instruments were general in concept, covering functions with broad market appeal. The unique requirements for CATV test instruments had to be realized with equipment which was not specifically designed for that purpose. Some of the compromises included frequency ranges, physical construction, and excessive operator control interface. Early instruments had complex mechanical linkage for tuning and gain control. More accurate instruments used hand-calibrated scales to compensate for component variation.

As varactors, pin diodes, and integrated circuits found their way into instruments, performance improved, more functions could be implemented in a given volume, and the front-panel controls become a complex of push-buttons, back-lighted rotary switches, digital readouts, and slide-rule dials. This continued until it was difficult to find the power switch in the maze of controls. These complex control panels allowed flexibility, but required an operator with a high degree of proficiency.

As we see it, the concept of microprocessor control reduces the complexity of the control panel and simplifies operator interface. The operator interface can now be "human engineered" with keyboard entries and alphanumeric readout of results, error messages, and system status. Perhaps the most important innovation of the microprocessor to instrument design is the fact that, because the instrument is a general set of hardware with a software instruction set, the software can be configured for specific instrument requirements with little or no change in hardware.

THE MICROPROCESSOR IN A NEW SIMULTANEOUS–SWEEP SYSTEM

There exists a trade-off in sweep response accuracy and potential interference to customers. We have purposed and conducted a study to show the subjective interference as a function of time in a channel with level and repetition rate as parameters. With data showing various optimum combinations of sweep level and in-channel time, the problem of broad-band vs. narrow-band recovery can be addressed.

Narrow-band recovery requires longer in-channel time and, therefore, low sweep level to satisfy the interference criteria. The resolution is minimal due to tracking bandwidth, especially in the areas of the channel carriers. Noise level is also a problem in longer cascades.

Broad-band recovery can utilize fast sweep time, but requires a higher level. The broad-band recovery method eliminates the tracking errors, reducing the problems to minimization of the sweep level and maximization of the resolution of the recovered response. Microprocessor control of the sweep transmitter and recovery systems is the key to solving these problems.

The microprocessor in the sweep transmitter allows the parameters to be entered via a keyboard and displayed on an LED readout. Inputs which are not in a programmed range are rejected. Valid inputs are used to set up digital-to-analog converters to control the sweep parameters.

The microprocessor uses a "look-up" table in memory to set the level in .1 dB steps. It also blanks the output and reads a counter at the beginning and end of the sweep period. Corrections are made via separate digital-to-analog converters, with the end frequencies nearly two orders of magnitude more accurate than obtainable with standard sweep generators.

Communication from the sweep transmitter to the recovery system receiver is by way of a carrier, phase-modulated with a serial ASCII code. Decoding at the recovery system tells the processor the start and stop frequencies, the sweep duration, and the repetition rate. The recovery system accepts data if it passes parity and check-sum tests.

Following the data transmission, the sweep transmitter uses the data link to send a pair of pulses. The recovery system reads these pulses as "pass one" and "pass two". The timing of these pulses is precisely controlled by the transmitter microprocessor, and allows cancellation of common sync by the recovery system. At the recovery system, the microprocessor controls the selection of preamplifier gain, which will optimize the signal to noise ratio for the recovered response.

When operating at near-carrier levels, the detected sweep response tends to show variations which limit the resolution of the instrument. The microprocessor provides several means to improve this situation. As the signals from the combined channels are summed into the detector, they create a DC value and a complex AC waveform. The low-frequency components of this waveform, as well as temperature-related DC and bias drift, are eliminated by an automatic-zero control circuit. This circuit holds the output of the detector at a constant level until the microprocessor sends a command which causes the circuit to maintain its last correcting value. Measurements are then made from that constant reference level.

Elimination of DC and low-frequency errors leaves the problem of sync pulses from many channels. Taking advantage of the data link, the pass one and pass two pulses previously mentioned are used to subtract the sync pulses from the response, which allows the resolution bandwidth to be maintained at a much higher value.

The recovery system reacts to the pass one signal, and converts a series of samples to digital data which are stored in sequence by the main random access memory. The timing from pass one to pass two is controlled so as to be within 1 usec of TV frame time. At pass two, the recovery system again converts a series of samples, but this time the sweep is also present. The difference between these two series of samples replaces the sequence in memory, which is recalled at a 60 Hz rate to refresh the CRT display. Since response data is stored in sequence, display timing and some logic controlled by the microprocessor can be used to convert the digital data back to an analog response at the CRT without using a special digital-to-analog converter.

After the recovery system has stored the sweep frequency response, the microprocessor inhibits the switch mode power regulators, powering down the RF section along with the analog-to-digital converter. The memory and CRT remain active as the timing circuits synchronize and refresh the display.

The recovery system processor uses the ASCII data to time out the sampled response. It also calculates the frequency and/or level of keyboard-controlled cursors as they are positioned on the display, the level being calculated as a function of a table in memory and the attenuator settings. When the Δ key is activated, the microprocessor calculates the difference between the two cursors. Results of these calculations are written on the CRT display in a format which is also controlled by the processor.

The microprocessor monitors the system and outputs error messages to the CRT such as: low battery, missing input, or attenuator changes.

Expansion of such a microprocessor-controlled instrument can be implemented by option cards or by interfacing additional packages via RS232 connectors.

Utilizing the microprocessor control and the data link, a system of this type can be set up to sweep the return system from a remote location back to the headend. At the headend or hub, the response can be coded on the data link and transmitted as data to the location under test, where it will be loaded into memory and displayed on the CRT.

Data in storage can be transferred from memory to magnetic cards or vice-versa with little change in the basic hardware. Memory can be added to perform digital averaging or normalization of response data.

The selection of a microprocessor for the sweep transmitter is based largely upon its support circuitry and software, while the main considerations for the recovery system microprocessor selection are low power consumption and its use of direct memory access.

DIGITAL DISPLAY STORAGE

Storage displays have typically been used to store information of the following types: the non-repetitive signal that would appear on a CRT momentarily, and then disappear; the signal that has a low repetition rate (usually below 40 Hz); and the low-duty-cycle signal that is too dim to observe. Until the early 1970's, the instrument manufacturer's solution to this problem was a storage-tube display. The storage-tube displays, while solving to some degree the problems previously described, left some problems to live with or still overcome. The displays would "flood" if the intensity were set too high or miss data if the intensity were set too low, and the cost would be higher than the standard CRT.

In the early 1970's, some of the instrument manufacturers began to develop digital storage displays. These displays are actually standard oscilliscope displays that are refreshed by semiconductor memories. The refresh rate is designed to be great enough to provide a flicker-free display.

The digital storage display provides some other advantages when combined with a microprocessor system. The stored data in the display memory can be accessed by the microprocessor and converted to a value easily read by the operator, and alphanumeric characters may be combined on the screen with the displayed data. This provides the operator with easy access to the processed data and a convient readout of the instrument setting. Since the data is stored in a RAM (random-access memory), there is no fadeout of the displayed data as long as the instrument power is on. Another advantageous feature if temporary storage is available is the transfer of the display data to the temporary storage area. This allows the operator to read the data at some later time to compare with more recently acquired data. This concept can be taken another step, the display data being transferred to non-volatile magnetic storage (card or tape) to be evaluated weeks or months later. This data could also be used for statistical processing on a computer.

The typical digital storage display system centers around a random-access read/write memory. The access to the memory and the timing of both the input and output is under the control of a control timing logic circuit. The input control and timing, as well as the type of analog to digital conversion performed, is a function of the type of signals to be converted. Some examples are: If the input data is slowly changing X-Y data, then both channels would probably be converted using tracking A-D converters, and a periodic sample window would be provided by the control timing logic circuit to the display memory; If the Y data is changing rapidly and the X input is a ramp, then a good approach is to use a tracking A-D converter on the X input and do a fast successive approximation conversion on the Y data whenever the X data changes; A third class of input signals to consider is a short burst of rapidly varying Y input data of a known duration, with the X input a timing pulse indicating the start of the Y data. In this case, the X input timing pulse may be used to reset a counter, and to cause the control timing logic to take access to the display memory away from the display and to give it to the input converter. At this time, the Y conversion takes place, the X counter is incremented, and the data is stored in memory. This cycle is repeated until the counter reaches it's final state, at which time the display memory access is passed back to the display.

The interface between the display memory and the display is dependent on the type of display used. Two that will be considered will be X-Y and raster scan. For the X-Y display, both the X and Y outputs come from D-A converters. The Y converter input is the display memory data, and the X converter input is the address of the data in the display memory. The control and timing logic increments to the next address. This process continues to the end of the display memory, when the address is reset to the start and the process is repeated.

In the raster scan, the memory data and address are converted to time intervals. The memory data is converted to a time interval from the bottom of the screen to the data dot. This conversion is made by loading the memory data into a counter and counting it down with the video clock during the upward trace of the beam. The data memory address is generated by a counter. The counter is advanced every vertical retrace, and is reset at each horizontal retrace.

DIGITAL SUBTRACTION

The storage of the data in digital form has provided us with an opportunity to improve the signal-to-background performance of our CATV Sweep Recovery System. The signals on the cable are nearly periodic at the TV frame rate. This may be taken advantage of by sampling the cable signal one frame prior to the sweep, then using this stored sample to subtract the background one frame later when the sweep is received. This is accomplished by transmitting two start-sweep pulses to the receiver. During the first pulse, no sweep is transmitted, resulting in the background being stored in the display memory. When the second pulse occurs, the sweep is transmitted. As the analog-to-digital conversions take place, the background data is read from display memory. This background data is converted to analog and subtracted from the input signal. The resulting difference signal is then converted to digital and stored in the display memory.

MICROPROCESSOR – CONTROLLED TIMING

The microprocessor is also used to control the major timing events of a system. In our recovery system, these major timing events are: the access of the operator to modify the system parameters (attenuation, cursor position, display mode, etc.); powering up the RF and A-D conversion circuitry and accepting the transmitter status; the receipt of the sweep data and processing of new cursor values for received data.

A time interval is made available to the operator by the processor to change the receiver status via the keypad. During this interval, the processor scans the keypad and responds to its commands. The length of this interval is derived from the sweep repetition rate data from the transmitter, and is converted by the microprocessor to the number of horizontal retraces to be counted.

When the processor has counted down the proper number of horizontal retraces, it quits scanning the keypad and applies power to the RF and A-D converter circuitry. The processor then samples a device which decodes the serial data sent from the transmitter on the pilot signal. The received data (sentinal character, start frequency, frequency span, sweep duration, sweep reptition rate, and check-sum) is stored in the processor memory. For the data to be considered valid, both the byte parity and check-sum must match. If the data received is not valid, it is ignored, and the previously received transmitter settings are used.

After the transmitter status data is received, the display memory control timing circuits are activated to receive the "pass one" and "pass two" sync pulses. The processor scans the control timing circuit waiting for an indication that the frequency sweep has been received. Upon receipt of the sweep, the processor turns off the power to the RF and A-D circuitry, and calculates new cursor values based on the received information.

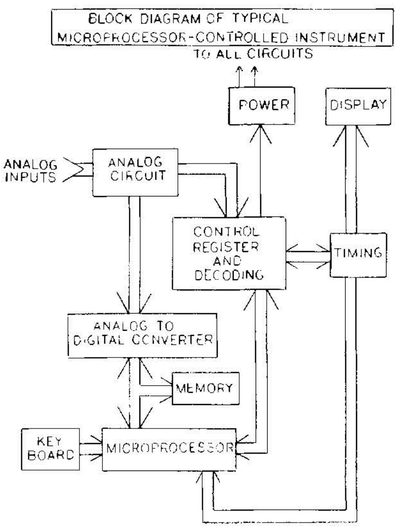
The microprocessor is limited in respect to the speed at which it can provide timing signals to the system. The vertical timing interval for the recovery system is an approximately 63 microsecond period. This interval is divided into 457 video clock cycles of about 140 nanoseconds each. The timing of the vertical information (characters, grid, data, cursors, and retrace) is controlled by discrete logic that operates at nanosecond switching speeds. Even some of the horizontal timing (request for new characters, grid, cursors, and retrace) is provided by discrete logic. The processor does aid in the horizontal timing by providing direct memory access for the display data, supplying the new characters when requested, and by resetting the direct-memory-access counter and character counter during horizontal retrace. These two counters reside in the memory of the microprocessor.

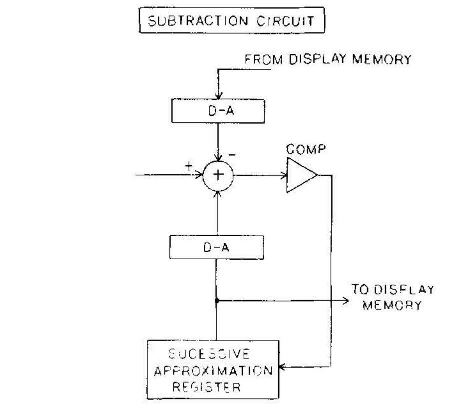
OPERATOR INTERFACE

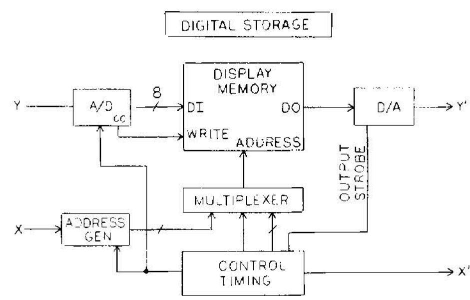
The operator interface for a microprocessor-controlled instrument may be made relatively simple, particularly when the instrument has alpha-numeric readout on a display CRT.

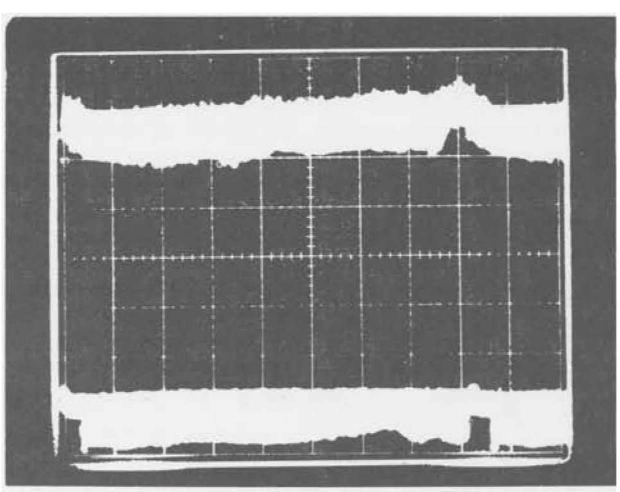
The system setting resides in the microprocessor memory. This allows the used of a simple matrix keypad instead of many rotary switches on the front panel. This keypad, along with the switches on the attenuator shaft, are connected to the microprocessor in such a way that the processor sees them as an extension of its internal memory.

The microprocessor (and its memory components) has made available to the designer the tools to design complex logic systems at low cost and small size. These same designs 10 years ago would have been at least an order of magnitude more costly, with approximately the same increase in size.

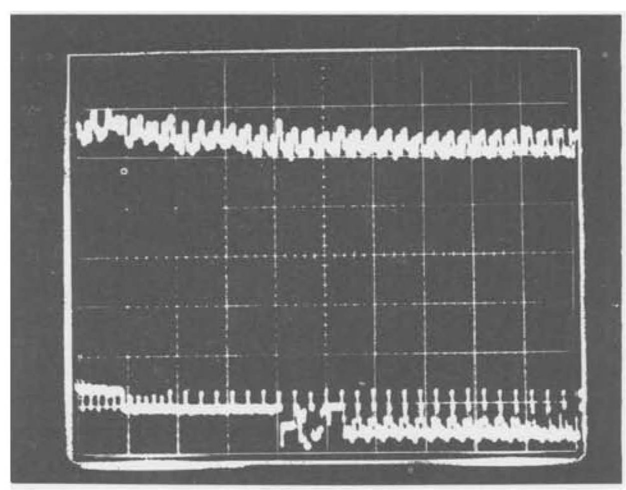




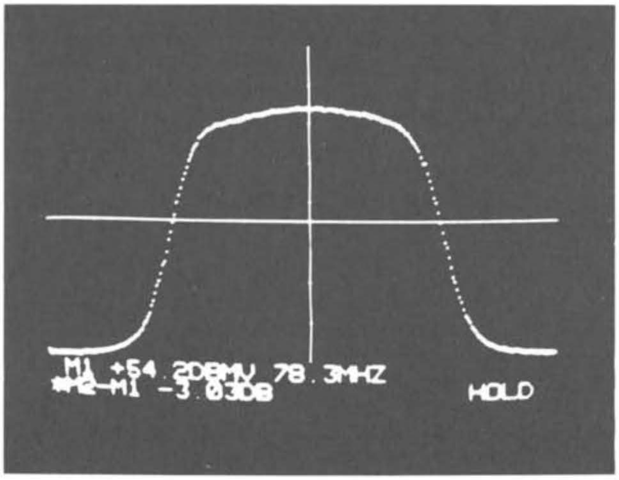




DETECTED OUTPUT FROM 12-CHANNEL SYSTEM.
CENTER LINE = GND. HORZ = 2 msec/div.
BOTTOM TRACE IS VIDEO FROM SINGLE CHANNEL USED TO TRIGGER SCOPE.



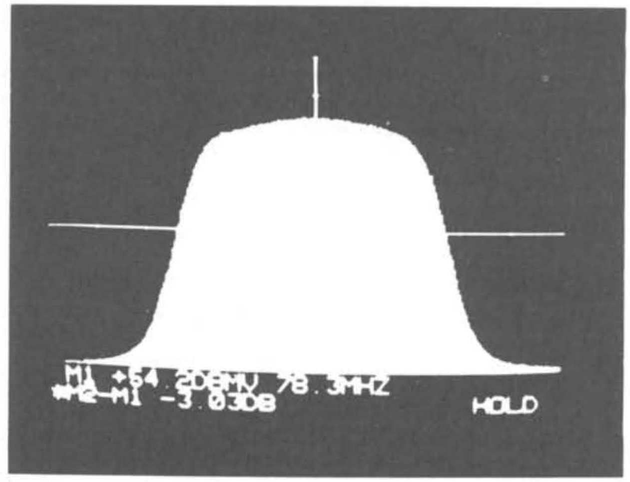
DETECTED OUTPUT FROM 12-CHANNEL SYSTEM.
CENTER LINE = GND. HORZ = .2 msec/div.
BOTTOM TRACE IS VIDEO FROM SINGLE CHANNEL USED TO TRIGGER SCOPE.



DOT MODE DISPLAY OF STORED DATA SHOWING LEVEL AND FREQUENCY CURSORS WITH ASSOCIATED ALPHANUMERIC DATA.

"M2 - M1" (Δ) INDICATES THE DIFFERENCE BETWEEN LEVEL AT CURSOR M2 (HORIZONTAL) AND LEVEL AT CURSOR M1 (VERTICAL).

"HOLD" INDICATES SYSTEM STATUS.



LINE MODE DISPLAY OF STORED DATA SHOWING LEVEL AND FREQUENCY CURSORS WITH ASSOCIATED ALPHANUMERIC DATA.

"M2 - M1" (Δ) INDICATES THE DIFFERENCE BETWEEN LEVEL AT CURSOR M2 (HORIZONTAL) AND LEVEL AT CURSOR M1 (VERTICAL).

"HOLD" INDICATES SYSTEM STATUS.

MULTI-INFORMATION SYSTEM USING FIBER OPTICS

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Kenzo Ohno and Tashuo Fujita

Matsushita Electric Industrial Co., Ltd.

I. Introduction

With the complication of the society and economy and with the higher standard of civilization, it is expected that necessary information should be provided to meet various requirements in many fields of individual life. It is desirable to develop new information systems such as two-way communication CATV system in order to meet such requirements. Several experimental two-way CATV systems are now developed in many countries.(1)

Progress in the field of optical fiber transmission has been accelerated since a low-loss fiber of 20 dB/Km was achieved in 1970.(2) Because of the notable advantages such as long distance transmission capability, enlargement of capacity, and construction flexibility etc., optical fiber transmission systems are expected to be applied in many fields. For a two-way CATV system application, the HI-OVIS system has been developed and experimented in Japan.(3)

The technology of two-way CATV system is classified into three major categories: various kinds of information filing, transmission of audio video, facsimile and data signals and information processing and control. For an optical transmission system, we have been developed optical transmitter, receiver and connector. Utilizing a new type of low reflection directional coupler, bidirectional video transmission through a single optical fiber has been experimented using same wavelength light sources at each end.(4) A still picture storage to use interactive information retreaval is one of fundamental file of system. For this purpose, a new optical video disk which is capable of instantaneous add-on recording and playback has been developed. Utilizing these newly-developed technologies, a new interactive information system using optical fiber has been experimented. This system is able to supply more advanced services, and has a more performance characteristics. In this paper, the configuration of the system is presented.

II. Discussion of Optical Fiber Information System

If an optical fiber cable is used as a transmission line, the structure of a signal distribution network becomes different from that of coaxial cable. Because of a linearity range of optical transmitter and receiver, it is difficult for a practical use to multiplex many video signals as in the coaxial cable by present technology. Therefore individual distribution line is necessary from signal source to terminal. A typical signal distribution network of optical fiber system consists of multiplexed trunk lines from center to demultiplexing points i.e. subcenters, and individual distribution lines from subcenter to terminals.

Generally, several signals are transmitted from center to terminals such as video signal with sound, data signal, facsimile signal and stereo sound. For transmission line, these signals are multiplexed as shown in Fig. 1. A frequency assignment should be selected so as to minimize the interference or beat of signals. Baseband TV signal transmission is used for simplicity of terminal equipment.

III. Feature of System

The optical fiber information system developed are composed of following technology, the computer control and communication, optical fiber transmission, storage of audio visual information, and home terminal. Several features of the system is as follows.

(1) Optical transmission: The development of directional coupler with low reflection accomplishes a bidirectional transmission through a single fiber. Using low loss connector and high efficiency optical transmitter and receiver, transmission of wide-band signal, for a long distance is made possible.

(2) Information processing: The distributed data processing network is accomplished by introducing a micro-computer at terminal and subcenter. Under the control of microprocessor, each center file is possible to operate as an individual subsystem.

(3) Information file: For still picture storage, large capacity and high access optical video disk is developed. Other equipment such as random access VCR and high S/N frame memory are also realized.

(4) Home terminal: Using a capacity sensitive touch keyboard, subscriber can request various information such as still picture, moving picture and facsimile. Combining terminal with equipment such as TV, FAX, FM, VTR and TV camera, home terminal can receive many services presented below.

Basic concept for program service development is as follows.

(1) New community development: Because of increasing complexity of social structure, the traditional local community has been destroyed. There are, however, still strong needs for the development of the new community. The system offers local community news by

video and hardcopy, mutual communication method by TV camera, microphone and facsimile.

(2) Information retreaval: Complexity of the society, progress of technology and cultual changes have caused individual to get his own subjective information more frequently. The system satisfies these needs instantaneously with audio-visual information and hardcopy.

(3) Home education: The system supports a various kinds of educational program in order for individual to catch up and well adapt ever-changing social environment.

The service of the system is shown in Table 1.

TABLE 1
Service of System

Service	Contents
Retransmission	Retransmission of broadcast channel
Local news	Local Origination Local Community news Living information
Video	Arranged video program (News, Sports, Show time)
Reservation	Rental video Reservation for cooking, shopping etc.
Education	Simple CAI problem and answer
Communication	Communication between terminals (camera, microphone, FAX)
Facsimile	Hardcopy (Memocopy) Document retreaval service
Home control	Control of home equipment
Home security	Fire sensor Burglar alarm

IV. System Configuration

The block diagram of the system is shown in Fig. 2. The system consists of center, subcenters, transmission lines and home terminals. Each terminal is connected to subcenter by single optical fiber.

In Fig. 2, request data from touch keyboard at a terminal is sent to subcenter controller. Collected data from terminals are transmitted to center communication controller. Processing the request data, center controller selects one of information files and send requested information to subcenter through frequency multiplexed trunk line. Each output signal of information files is multiplexed as shown in Fig. 1. At subcenter, trunk line signals are demultiplexed and enter each corresponding switcher. According to the control data from the center, switcher distributes trunk line signals to individual line. Still picture is stored in frame memory at subcenter, and the video signal is transmitted to terminal.

(1) Center: Center consists of system controller and information files. System controller is a minicomputer with disks and ICU (interface control unit). For an information file of still picture, optical video disk is developed. The disk is able to record 20,000 frame pictures and access randomly within a half mili-second. There are several ordinary video cassette players for use of video service and local origination In addition to these, random access VCR which is able to access any position of a cassette video tape is used for video retreaval and transmission reservation service. Audio and facsimile information is stored in a digital disk after being processed and compressed.

(2) Subcenter: Subcenter consists of frame memory, switcher and controller. Using a high S/N magnetic sheet frame memory, high quality still picture reception is accomplished. To make an effective use of frame memory, it is installed in subcenter instead of terminals. Data transmission between center-subcenter and subcenter-terminal each of 48 K bps and 9600 bps respectively, is controlled by subcenter microcomputer. Control of switchers for signal distribution and assignment of frame memory to terminals is also controlled by the subcenter processor. Outline of center and subcenter equipment is listed in Table 2.

TABLE 2
Outline of System

Item	Outline
System configuration	Center and Subcenters
Number of terminals	300 Terminals/Subcenter 20 Subcenters/Center
Data transmission	48 K bps (Center to Subcenter) 9600 bps (Subcenter to Terminal)
Network	Trunk line (to Subcenter) Distribution line (to terminal)
Optical Video Disk	Capacity 20,000 frames Access time 0.5 ms
Random Access VCR	Numb. of material $1 \sim 30$
Audio File	ADPCM, 3 ch TDM
Frame Memory	Magnetic Sheet, S/N 50 dB
System Controller	Minicomputer PFU-300 Microcomputer L-16A

(3) Optical transmission line: As mentioned in Chap III, bidirectional transmission through a single fiber is achieved by use of

directional coupler. Schematic configuration of the transmission system is shown in Fig.3. Characteristics of trunk and distribution line are listed in Table 3 and characteristics of optical elements are shown in Table 4.

TABLE 3
Characteristics of Optical Transmission Line

Transmission system	Characteristics	
Bidirectional transmission	Bidirectional transmission	Same wavelength and frequency
	Transmitter	LED
	Receiver	PIN
	Optical fiber	Step index
Long-distance transmission	Modulation	FM-IM
	Frequency	22MHz ± 6MHz
	Transmitter	LD
	Receiver	APD
	Optical fiber	Graded index
Wideband transmission	Modulation	Analog-IM (30.8MHz)
	Bandwidth	45MHz (-3 dB)
	Transmitter	LED
	Receiver	PIN
	Optical fiber	Step index

TABLE 4
Characteristics of Optical Component

Component	Loss	Reflection(%)
Connector	< 0.7	< 0.05
Directional Coupler	3.7	< 0.0025
Splice	0.1	< 0.02
PIN	—	< 0.02
LED	12	< 0.5

(4) Home terminal. Home terminal consists of keyboard, terminal controller, TV, FM, FAX receivers, VTR, camera and microphone. The picture is shown in Fig. 4. Touch key and display of entry data are controlled by 4 bit microcomputer. Terminal controller has also a processer and the terminal can be easily expanded to have a home computer capability. Connecting a video RAM to the terminal, BASIC program can be developed independently. Developed programs can be transferred to center digital files for individual person.

V. Conclusion

In this paper, visual information system which offers still picture, moving picture, stereo sound, hardcopy and TV or facsimile communication services has been presented. Utilizing advanced technique such as optical fiber transmission, large information files, communication and control, the system has achieved higher performance characteristics and higher grade of service than ever. This system has been experimented for verification of hardware and evaluation of services in our laboratory.

Acknowledgement

The authors wish to thank Dr. K. Iga, Dr. M. Fukai, Mr. K. Tatematsu, Mr. I. Senbokuya for their encouragements. Thanks are also due to Mr. T. Tsutsumi and Mr. T. Yoshida for their developments of relevant equipment.

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(3) M. Kawahata and K. Kohnushi, "Visual Information System - HI-OVIS -", J. of Ins. of TV Eng., Vol. 32, No. 4, 1978.

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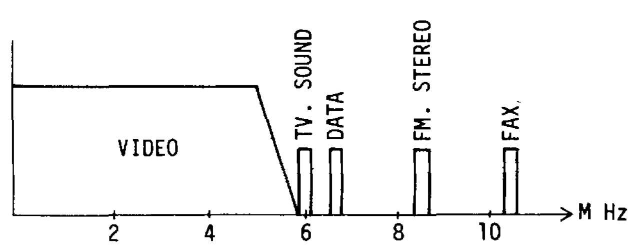

Fig.1. Frequency Allocation.

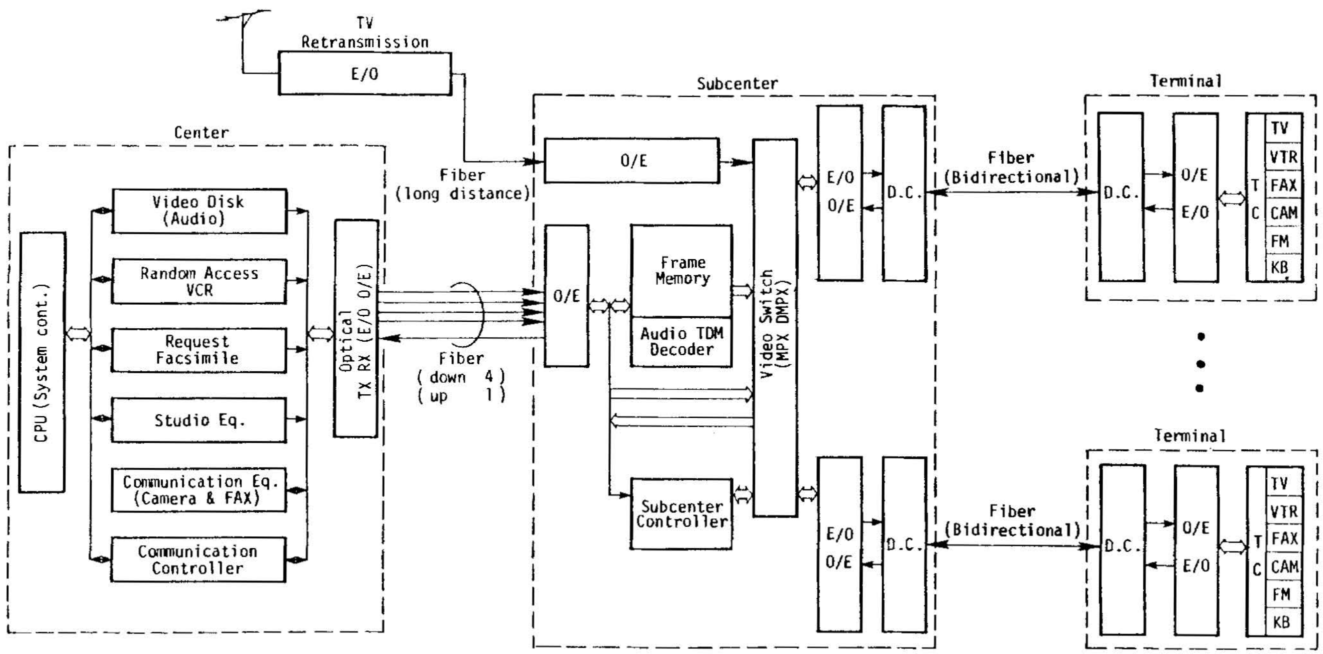

Fig.2. Block diagram of system.

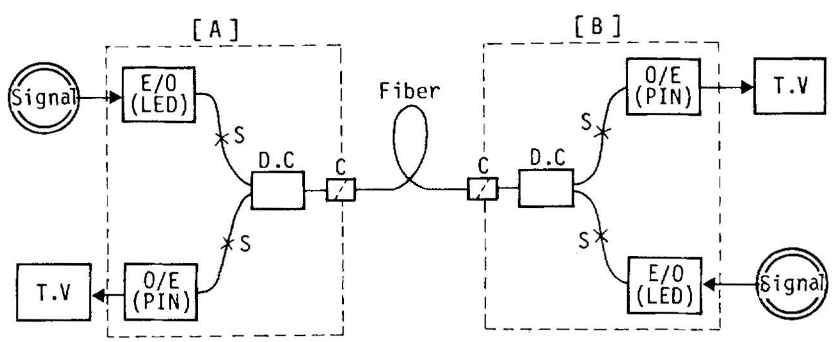

Fig.3. Block diagram of bidirectional transmission system.

Fig.4. Picture of terminal

NARROW-BAND VIDEO:
THE UPI "NEWSTIME" TECHNOLOGY

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July 3, 1978, marked the beginning of a new era in visual communications. On that date United Press, International, inaugurated "NEWSTIME" programming which combined audio and slow scan television to provide a unique new information service to cable TV systems throughout the United States. In NEWSTIME, UPI effectively combined the elements of still images from wirephoto and slide sources, audio from remote feeds and studio production, plus information from many sources to produce a basic 15-minute news show, transmitted 24 hours a day, with frequent updates.

The use of slow scan television is a key factor in providing economical transmission of the video portion of NEWSTIME. A bandwidth of only 8 kiloHertz allows a picture update time of 8½ seconds, with the viewer seeing a horizontal "wipe" when a new image is transmitted. Eight kiloHertz channels are not too common in the case of terrestrial communications, and consequently satellite transmission via RCA Satcom was chosen for signal distribution. Slow scan video and audio are "piggy-backed" above the baseband video signal of Super Station WTCG in Atlanta by means of two low-amplitude subcarriers at 6.2 megaHertz for video and 7.4 megaHertz for audio.

Figure 1. UPI NEWSTIME PRODUCTION FACILITIES AT DOUGLASVILLE, GEORGIA

The NEWSTIME program starts out with "real time" video, is scan-converted to narrow-band TV for transmission, and then reconverted to EIA standards for normal distribution throughout the cable system. This approach provides a great deal of program production flexibility using readily available, conventional hardware. Three-quarter-inch, U-Matic video cassette recorders were chosen as the most convenient method of assembly, editing, and playback of the combined audio-video program. Audio is reproduced normally, while the video portion of the tape playback is fed to a sampling type of scan converter which produces a high quality slow-scan TV signal.

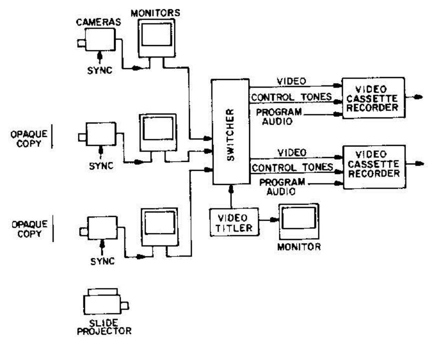

Figure 2. BLOCK DIAGRAM OF UPI PRODUCTION EQUIPMENT

The scan conversion process involves taking one narrow sample from each line of the active TV raster, starting at the upper left hand corner of the picture and generating a vertical column or visual "slit". Each of these samples (less than 100 nanoseconds wide) is then "stretched" out to approximately 64 microseconds, thus filling in the gaps. On succeeding TV fields, the sample row is slowly moved from left to right to convert the entire image. The field rate of the original video signal now becomes the line rate of the slow scan TV signal, and the scanning format is rotated 90 degrees. Line sync pulses are added to the slow scan video in a fairly conventional manner, except that two separate widths of sync pulses are used in order to identify the field from which the original sampled information came. A short 400 Hertz tone also precedes the start of each new image in order to initiate the picture reconversion process at the receiving station scan converter. A more comprehensive description of the slow scan signal format is listed in table one, but it is important to note one other special characteristic, that of "dot-interlace", which results in a subjectively superior picture with reduced number of picture elements, an important consideration in terms of faster transmission times and in the lowering of memory size requirements at the receiver.

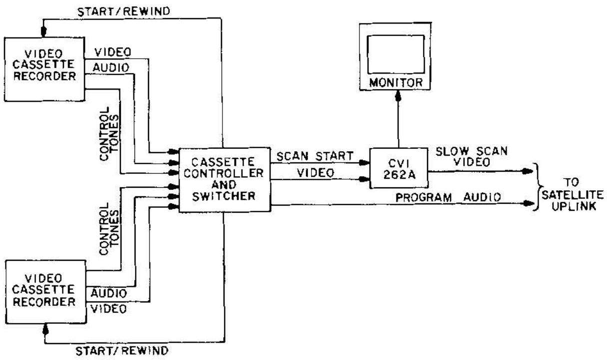

Figure 3. BLOCK DIAGRAM OF UPI SCAN CONVERSION SYSTEM

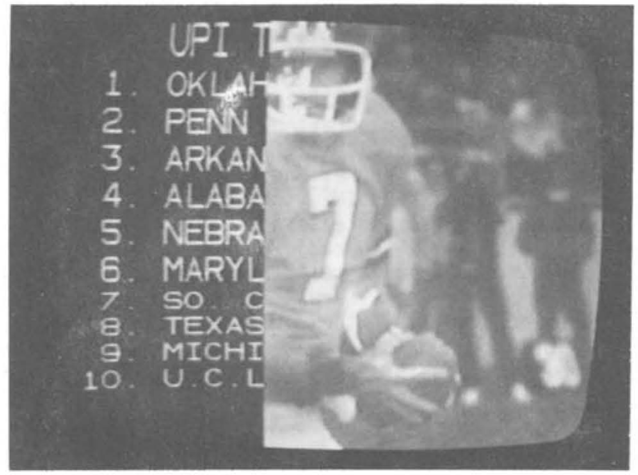

Figure 4. OFF-SCREEN PICTURE OF RECONSTRUCTED SLOW SCAN TV SIGNAL MID-WIPE

The sampling scan converter is a relatively simple device which produces high quality output signals. It does, however, require that the video signal fed into it be "stationary" for the length of time required for the conversion process. This condition is easily met by continuously recording an image for 9 seconds on the video cassette tape, and using a short tone burst on the second tape audio channel to start the sampling procedure.

The present NEWSTIME system reproduces monochrome pictures only, but provision has been made for later addition of color. The first step in this direction will probably be the incorporation of colored titles, borders, or simple graphics. It is also feasible to generate full color images with slow scan TV technology, but program production factors and other considerations make the introduction of this form of transmission somewhat further downstream.

The receiving part of the NEWSTIME system uses a standard earth station with a two-channel subcarrier demodulator recovering audio and slow scan signals. Again, the audio portion is used directly, but the slow scan video is fed to a scan converter which reconstructs the original pictures in conventional EIA format for subsequent distribution over the cable system. The receiving converter is actually more complex than the one used at the transmitter because of the need to incorporate a memory capable of storing a complete image. Solid state computer technology is used for this purpose, and the memory is organized as 256 x 256 picture elements per field with 6 bits per element for grayscale, giving a capability of 64 shades of gray. The dot-interlace format used means that picture elements are "staggered" horizontally on a field-to-field basis, giving greatly improved subjective horizontal resolution. An EIA test pattern reproduction will appear to have nearly normal vertical resolution and approximately 270 lines on the lateral axis.

An internal sync generator with gen-lock capability provides timing for the receiving scan converter. The gen-lock allows additional operational flexibility for the cable operator in terms of local titling or signal mixing. The sync generator also produces a 3.58 megaHertz subcarrier signal for use with external "colorizing" circuits.

NEWSTIME has opened up some important opportunities in providing a variety of economical special services. The relatively small video bandwidths used means that many channels could be added to existing and proposed satellite transponders. In fact, if a single transponder were devoted to transmissions of this nature, it could handle approximately 100 simultaneous slow scan plus audio programs. News, information, instruction, and teleconferencing applications are all adaptable to the slow scan format. Not only is transmission much more economical than "real time" TV, but program production may be greatly simplified, even down to a one-person operation.

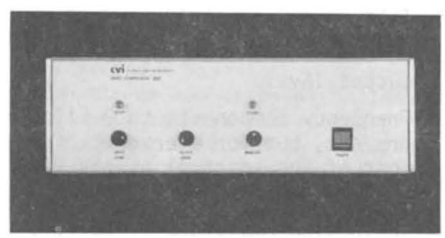

Figure 5. COLORADO VIDEO MODEL 262A VIDEO COMPRESSOR

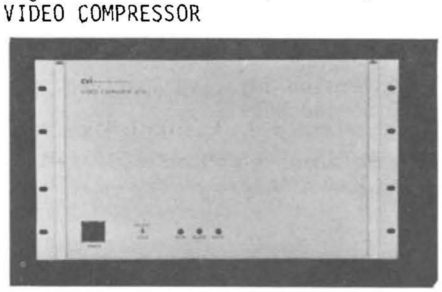

Figure 6. COLORADO VIDEO MODEL 275 VIDEO EXPANDER

On the local level, slow scan TV can mean special services that would be completely impractical otherwise. Literally hundreds of narrow band video signals can be "stuffed in the cracks" of the cable system to interconnect schools, fire departments, police stations, hospitals, and other institutions with visual communications. Even when the final pictures end up on a broadband channel, as in NEWSTIME, the relatively low production costs and ease of multi-point program origination, via the cable or dedicated telephone lines, can provide some attractive opportunities.

The present thrust of technology appears to be definitely in the direction of improved performance and lower costs of slow scan TV hardware. The possibilities seem well worth investigating by the cable industry.

Table One
UPI NEWSTIME SLOW SCAN TV SIGNAL FORMAT

Line: Scans perpendicularly, top to bottom, at a rate of 60 lines/second. Line is composed of sampled data with the number of elements being equivalent to the number of lines in one field of the input signal. Line blanking interval is the same as the field blanking of the input signal. Adjacent slow scan lines will be "dot-interlaced" due to the 2:1 interlace characteristics of the input signal. Resolution is essentially the same as the vertical resolution of the input signal.

Line sync is 0 to -2 volts, .5 ms or 1 ms duration depending on field sampled.

Frame: A 400 Hertz "start burst" precedes the initiation of the frame which scans horizontally from left to right at a rate of 8.53 seconds per picture. Horizontal conversion linearity is 1% or better.

Video: -DC coupled, white postiive, 0 to 4 volt output level.

-Frequency components to 8 kiloHertz may be present, but for average pictorial material most of the spectral energy will occur at 60 Hertz and harmonics thereof.

-Conversion Amplitude Linearity: less than 3% distortion.

-Conversion Signal to Noise Ratio: 40 db unweighted.

-Conversion Sampling Aperture: nominally 50 nanoseconds.

-0-

PAY PER VIEW, SECURITY, AND ENERGY CONTROLS
VIA CABLE: THE RIPPLING RIVER PROJECT

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Abstract.

Control of Pay Channels, Security Systems, Energy Controls, and Meter Reading have been talked about or demonstrated on an experimental basis. This paper describes the implementation of an actual CATV system located in Wemme, Oregon to begin operation in early 1979. The system will utilize two-way data communications on the cable to offer each resident a choice of Cable, Premium TV, Security, and Energy Control systems. Metering and load shape reading will be demonstrated in conjunction with the local power company.

Security, Energy, and Pay Per View Services offered to Two-way cable subscribers.

A small planned community in Oregon will soon be the site of a test of on-line security and energy control services in addition to the entertainment services normally provided by cable. The system is the first test nationally to utilize a controller designed by C.B. Schrock and Associates, Inc. of Aloha, Oregon. The first system serves to demonstrate the versatility of the universal data handling system that the Company has developed.

The home unit called a Universal Addressable Data Terminal (UADT) is a microprocessor based controller that converts the cable to a data bus and then reads the bus back into the cable. Functional modules containing a minimum of hardware are then plugged onto the UADT "bus". Modules in production today include CATV and Pay, Security, and Energy. The capability for any other services such as polling of subscribers, utility demand reading, status monitoring, and sophisticated data services such as credit card verification and point of sale terminals are all easily accommodated with speciality modules.

Headend control and protocol (or language) of the system is also very basic. A major design goal was to provide a simple system so that a typical system operator could use and change operation easily, without hiring an expensive computer programmer. The ASCII standard found on most teletype and home computers is used for all commands. To interrogated a box in the system, four ASCII characters selects any box, two more select the module, and a question mark (?)or (ENQ) interrogates the status of the box. The sub-modules are also controlled (such as turning off lights or a furnance) with two characters per module.

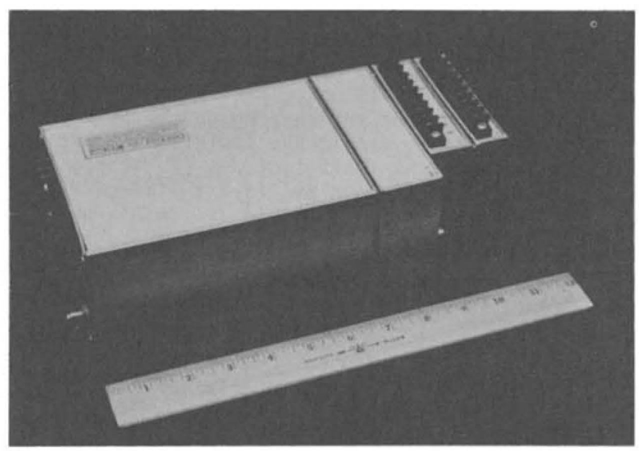


Figure 1. Universal Addressable Data Terminal for cable television systems is shown with a cable and preimium control, a security and alarm, and energy modules installed. Unit is mounted in any protected area and the house drop is looped through the unit.

Advantages over other systems.

A number of systems have been proposed or are in use that use single direction or the bi-directional capability of the cable for alarms, tap control, subscriber polling, energy controls, and TV selection or rating.

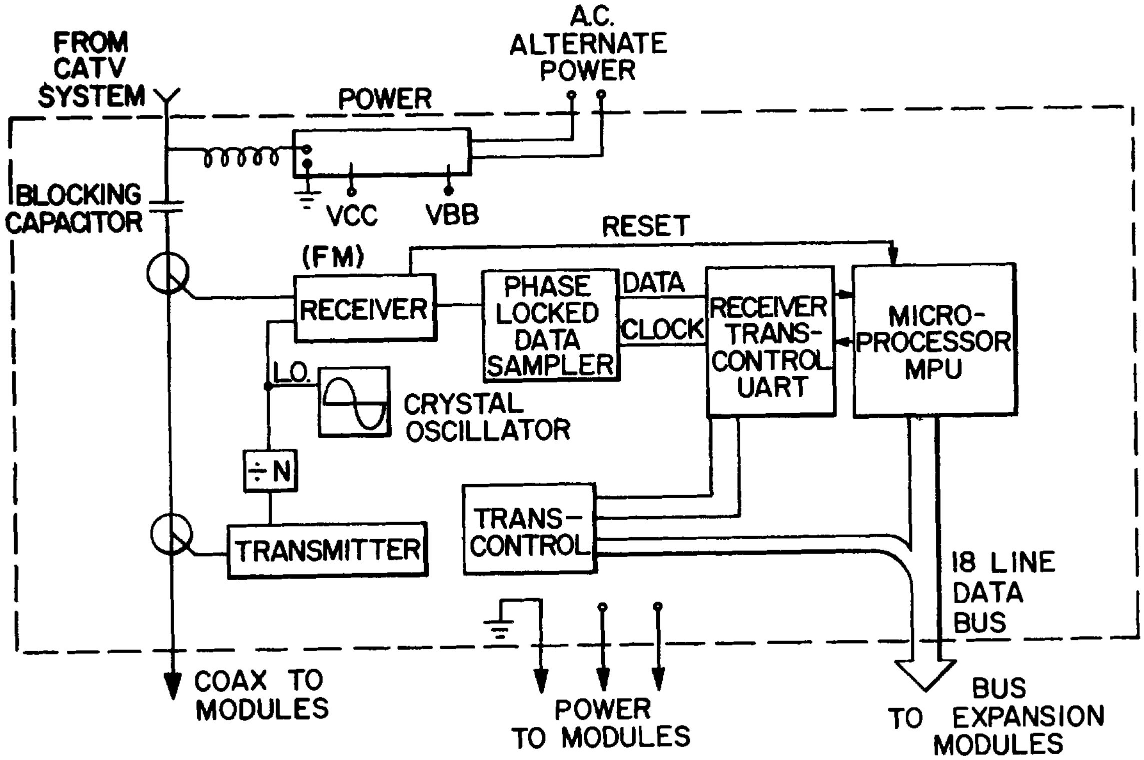


Figure 2. The UADT home terminal contains a receiver, transmitter, power supply, and a microprocessor controlled data converter. The receiver and transmitter share the same crystal oscillator.

Each home or remote terminal usually houses what is felt to be an optimum configuration for the speciality service desired and the data transmission format is chosen for the job. These systems are then polled or updated by a central computer.

The present approaches, however, cause a number of problems. The hardware and the data length are fixed at the time of manufacture inhibiting the capability for services which may not of been envisioned. The concept of polling individual subscribers in a rapid fashion necessary to detect changes (such as an alarm) is very wasteful of the data transmission medium, especially when the probability of an alarm is very low.

The present two-way service devices in-mass also raise another major problem, that is the need for multiple headend computers, carrier frequencies, data formats, all of which are incompatible with each other.

The new system offers both hardware and software expandibility. Virtually all cable Blue Sky Services are data services so the Company has produced an efficient data handler. A mix and match system using one of the international data standards is considered to be the only approach that will not be obsolete before it is installed.

Accordingly, the microprocessor based controller uses a fast, but accurate data format, and has a number of operating modes including a Simple mode for home alarms, a Complex mode for data services, and a All Call or Service request mode for alarms and interrupts. All modes are available in each controller and can co-exist on the same system carrier.

The Central Headend Computer.

A central processor or computer is located at the headend or any other single location within the system. The interface unit provided by the company consists of data storage, serial to parallel converters, and the necessary RF transmitter and receiver to interface to the system. A single parallel standard plug (Centronics Standard) is chosen depending upon the number of subscribers and the task. Anything from a simple TTY or home computer, to a complex commerical million dollar unit can be connected. This flexibility allows an operator to start small, possibly experiment, then upgrade without having to buy new home terminals or a new headend interface.

The computer controller is outfitted with peripheral off the shelf devices such as remote printers (possibly located in a fire, police, or dispatch location). For larger systems additional memory in the form of large core, disc, or tape can be connected so that information can be obtained "on line" to aid in the dispatching of fire, police, energy and the non-specified functions.

Interconnection capability from the computer is provided to external sources or computers such as banks, utility company computers, information sources, as deemed desirable by the CATV system so that data originating in the CATV system, or desired in the system, can be freely transmitted bidirectionally from external sources to or from any point in the system.

The entire headend interface "modem" is housed in a single rack width 3-1/2 inch high unit. It is supplied complete with a 24 hour real-time clock, audible alarm and external outputs, and an RS-232 interface for remote or local printer use. Priced at $2000, the unit provides all headend functions except for the actual computer. With the present home computers that are available, the entire headend for a small control system could be implemented for under $4000.

Technical Details of the System.

Serial Data Signals on a FM carrier along with CATV television signals enter the UADT data through a coax connector (74 or 118-136 MHz). An inductor taps the incoming RF line connecting to the powering compartment in so that cable powering of the device can be accomplished if desired. A blocking capacitor isolates cable powering and an MOV device protects the box from transients, passing only RF signals. An RF stripline on the motherboard contains directional complers for the receiver and transmitter.

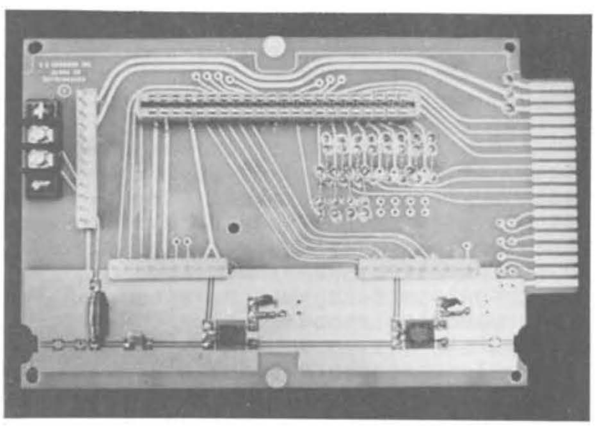


Figure 3. Motherboard contains RF couplers for the receiver and transmitter (lower edge) and primary address coding (right center).

The receiver combines many special features to provide accurate data handling capability and reliability with low cost. The receiver is a crystal controlled, super-hetrodyne FM design using very low parts count. The receiver consists of an input preselector, J-FET mixer--amplifier, single crystal oscillator, and a ceramic filter IF. A single IC is the IF, detector, and audio amplifier. A simple comparitor and DC restore circuit provide clean data for the MPU board.

The heart of the UADT is a microprocessor (MPU) using a propriatary program, the microprocessor locks onto the incoming data stream and generates synchronous clocking. The header and address of incoming signals are compared to a diode matrix on the motherboard until the address of the location is recognized. The MPU then latches the sub-address and message to the output bus of the data terminals. If commanded to read, the same sub-address and output bus is strobed in reverse, and the data is regenerated in a serial sequence and transmitted to the central controller.

The entire digital function of the UADT is performed using a single chip MPU located on one circuit card that plugs onto the motherboard. Two data speeds are being offered; an extremely low cost 2400 baud unit, or a 30K baud standard MPU.

The transmitter is a simple keyed CW design using existing state of the art design followed by a harmonic L.P. filter. The transmitter has four failsafe systems to prevent accidental runaway, since this single defect could lockup the systems. The safeties are: MPU data checks to guard against continuous data being fed to the transmitter, power supply pulldown in event of continuous transmission, and an R.F. monitor point that is checked by the MPU. In event of all three failures, the UADT can, on command, blow a fusable link powering the transmitter.

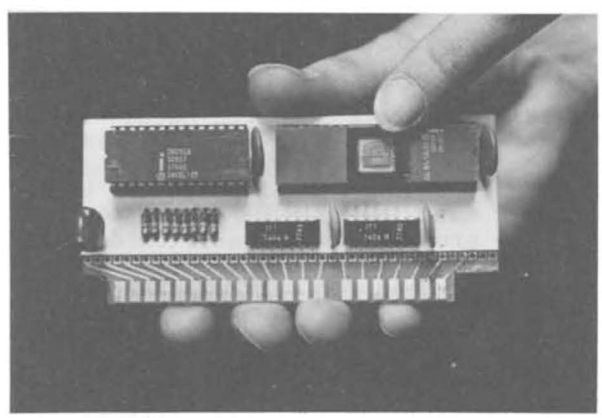


Figure 4. A prototype of the high speed (30 kB) MPU is shown. A single chip microcomputer (Intel 8048) performs all address recognition, formatting, supervision, and self test of the home unit.

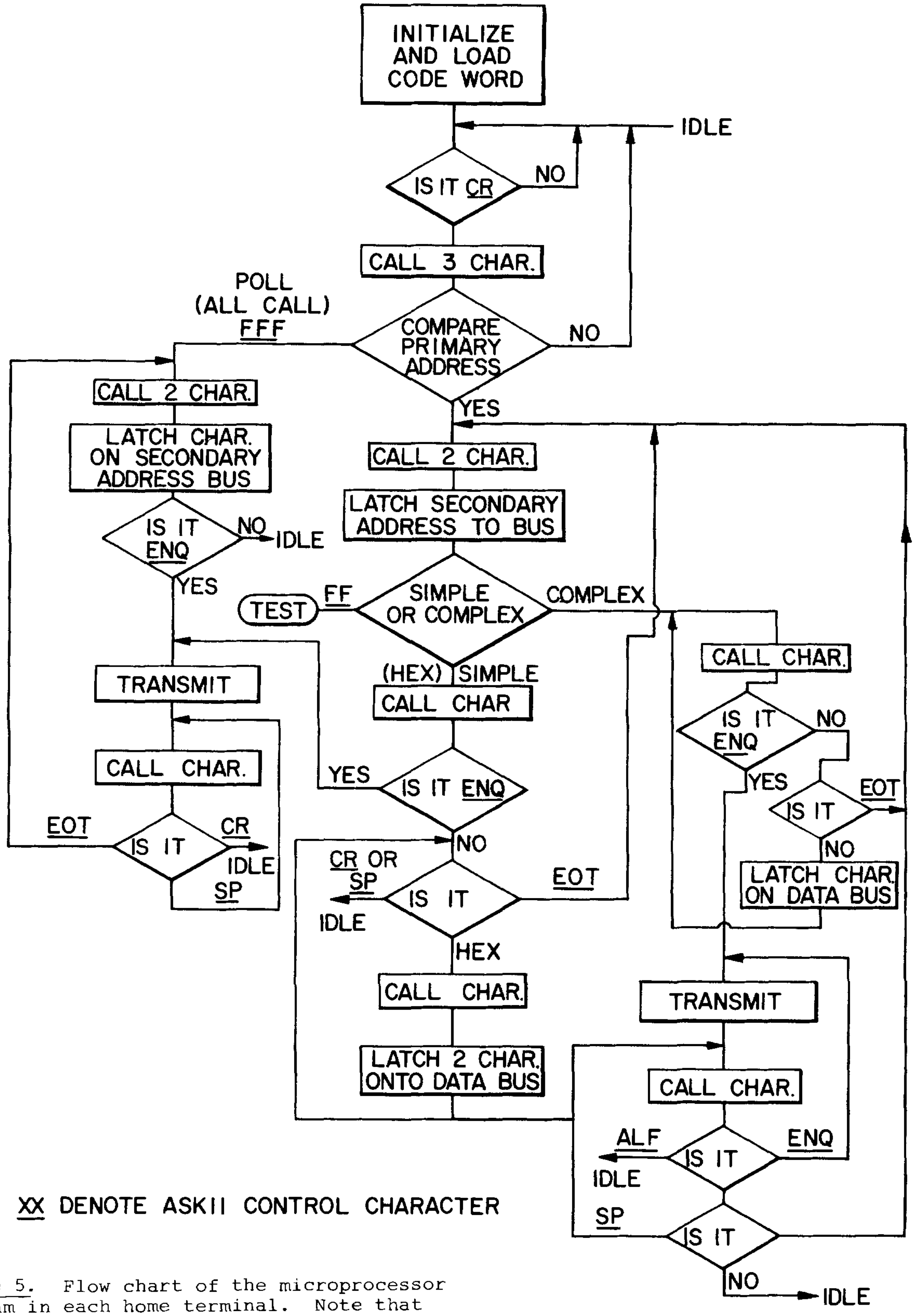


Figure 5. Flow chart of the microprocessor program in each home terminal. Note that three control modes are available: Simple Complex, and the All Call. Modes are automatically selected by downstream data.

A unique feature of the receiver system is the clock regenerator. Rather than encode clock onto the data stream which requires additional bandwidth, the system idles between transmissions with a half-rate clock signals. All messages are sent synchronously without header information on each bit. The clock is extracted directly from the data using a phase lock loop sample and hold regenerator. The circuit consists of an edge finder, driving an error amplifier. Whenever a data transition occurs, it is compared to the internal, free running clock. If an error exists, a sample and hold voltage is applied to the oscillator. Because data or "idle" clock is continuously present, long time constants are chosen so that it takes many clock transitions to either drift or correct an error. This has proven to be effective for reliable data transmission.

Expandability is provided by establishing the intermediate bus. The bus consists of 8 data lines and 8 address lines, as well as read, write, and simple control lines. Powering is also available on the bus. A push on R.F., coax connector is also a part of this bus. The bus was established to permit external modularity and expandability. Simple decoding to the bus for low cost services can be accomplished with a handful of parts. However, the design permits complex, or large numbers, or both to be accommodated. The R.F. portion of the bus can be continued for functions such as CATV switching. Using a narrower module that only fits over the data bus, functions such as alarms or energy controls not requiring R.F. can be accommodated.

The protocal of the system has a number of special features to allow for simple low cost operation, with expandability to complex operations. Each UADT terminal has the capability of 256 function modules. However, in the SIMPLE mode, determined automatically by the commands received, each home box is simplified to handle seven modules, which is adequate for most residences. For larger installations, such as apartments or businesses, the COMPLEX mode can be software selected, and allows up to 256 modules or functions at each UADT. The COMPLEX mode also can handle serial data transmission. Mass interrogation of critical functions such as alarms is accomplished using a binary tree sequence. Since most alarm functions occur only occasionally during the year, continual interrogation is felt to be inefficient. Test routines are built into the system to allow for: Parity and checksum on data as necessary, command control and shut-down of transmitter, continual verification of the status of all terminals, transmitter, receiver, and power supply status of terminals. A distress signal will be sent to the central computer by a box in event of tampering, power failure, or other problems within the home unit.

Cost reduction in design.

Some of the features that achieved the low terminal cost are the use of a simple receiver. The FM receiver uses minimum parts count, a ceramic IF filter and a single FM chip IF discriminator. Receiver and transmitter can share a common crystal oscillator. An AM return channel transmission scheme is used for simplicity in the transmitter design, as well as decreasing the acquire time at the central receiver location.

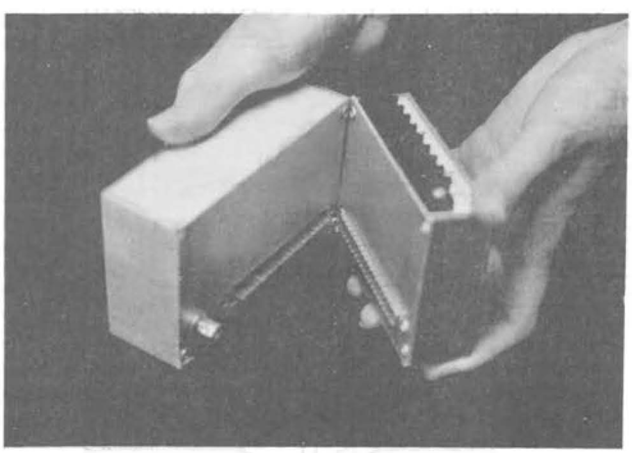


Figure 6. The bus extends through each specialty module. Up to 256 specialty modules could theoretically be stacked onto one UADT.

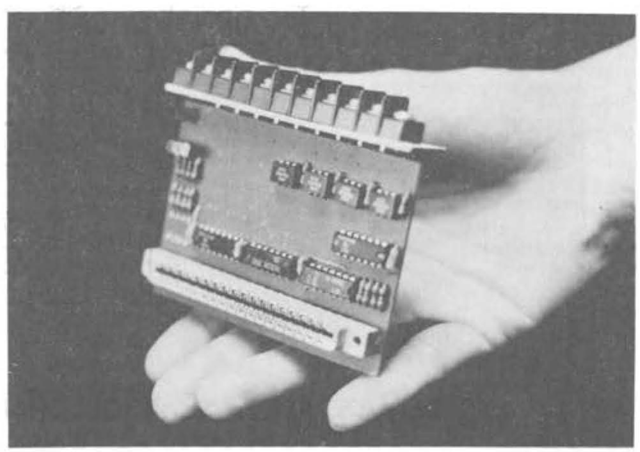


Figure 7. Each specialty module contains this master decode board. Depending upon the functions required, the board can be loaded with input-output drivers and isolators. A 4-input module is shown.

However, the biggest cost reduction is due to the use of the single chip microcomputer. A crude version of the box was executed a few years ago requiring over 50 TTL packages but was not cost effective. The real breakthough in design cost and flexibility, however, came with the introduction of the single chip microcomputer. The basic home controller has been designed around the Intel 8048 chip.

An entire home system fully loaded with four modules (TV and Pay TV, Security, Energy, and Meter Reading) can be installed for as little as $700 including all the hardware and labor. The cost of the system can be added to the price of a new home. Older homes can be easily retro-fitted for various services due to a unique kit approach to the energy and alarm controls. The Company feels that existing CATV installers could be adapted to perform the additional installations for the extra services.

<u>The first system.</u>

The first commercial installation of the system is in Rippling River, a planned community and convention center in Oregon that will eventually have 980 residential units. The homes will each have their own controller (UADT) while the condominium-type dwellings will be served, four or eight units per controller. All homeowners will have the choice of Cable TV, movies from a satellite receive station, alarm service, energy conservation, and meter reading (paid by the utility company). In addition, extra functions have been provided in the form of a message light system and TV theft alarm for all rentable units. The system will be in operation in mid-summer of 1979.

The developers of the planned community feel that the biggest advantage of this system over stand-alone home computers is the central reporting function. A large data base and computer can be located in the lodge and office facility. Alarms, for instance, will be dispatched to the appropriate agency with complete information such as the location within the home, nearest fire hydrant, name of insurance company, and any medical problems noted for the resident.

Energy controls are much more sophisticated than a stand-alone system since the central computer can factor weather forecasts, ground moisture, outside temperature, and total energy demand.

The Rippling River's CATV system will include the following system:

- Television and FM service — 5 local off-air TV stations, message channel, weather channel, and Channel 17 (via satellite).
- Premium Movie Service— Pay per view (via satellite).
- Security — Entry alarms, fire alarms, emergency alert panel (Fire, Police, Medic), and a light cycling outlet. $400 installation and $11 per month.
- Energy Conservation — Termperature turndown, waterheater control, outside lighting control, sprinkler controls and load leveling. $200 installation, $6 per month.

Other services at the community utilizing the coax cable will be a message light system for rentable rooms, a TV theft alarm, holding tank alarms, and an extensive CCTV system covering the golf courses, tennis courts, swimming pools, and night parking areas.

The data headend contains a dual DEC PDP-11-32 controller with remote printing terminals in the convention center and dispatch location: The entire CATV system, headend, and home terminals will have a minimum of four hours stand-by power.

POTENTIAL USE OF MICROCOMPUTERS

THE THREATS TO TECHNICAL PERSONNEL, MANUFACTURERS AND OWNERS

Raymond E. Daly IV
President

Computer Cablevision, Inc.
Washington, D. C.

Abstract

The two-edged sword of microcomputers is becoming apparent to many cable television technical personnel, managers and owners. While the potential uses abound, microcomputers are threatening cable television. The way systems are evaluated is threatened. The lack of programs for cable television threatens this industry. Microcomputers threaten the present methods of electronic design. And the competition will use microcomputers to threaten the industry. The impact of microcomputers could be as much or more than the impact of satellite distribution if the challenges are met.

The problem is the computer. No, they're not expensive any more. That may be part of the problem. No, they're not difficult to use. And that may be part of the problem. And no, they're not unreliable. And this too may be part of the problem. But they do pose a threat.

THREAT TO PRESENT WAY OF EVALUATING BUSINESS

The advance of electronics has brought a variety of marvels. The introduction of satellites to cable television by Home Box Office and RCA threatened the previous ways of doing business in the industry. Now it is standard procedure to consider satellite reception as part of any cable television system. Regardless of whether an earth terminal for receiving satellite signals is already used in the plant, the value of the system is affected by this technology.

With microcomputers the previous ways of doing business are likewise threatened. Just as most technical personnel may have thought that HBO's decision to distribute via satellite would never effect them or their cable system, the same is probably true about how you think about microcomputers and cable television.

Cable television is in the forefront of satellite distribution. Now public television, radio networks, and some broadcast television syndicators are joining in. And broadcast television networks are not far behind, perhaps just waiting for AT&T. But, the people in this industry have kept pace with the developments in this technology and this has produced results.

THREAT OF COMPUTER SOFTWARE

With microcomputers it appears that several people are also concerned. Many are so concerned that they have spent their own hard earned money to buy a microcomputer. Several small systems have purchased them. And some of the larger companies either have purchased or are considering purchase of microcomputers for their personnel.

Articles in the trade press, like my column "On Computers" in CATJ, and presentations and papers like this one support computer users. Each month in my column a short program is listed which helps solve a cable television problem. To date these programs include: "Geostationary Satellite Finder", "Cable Power Design", "Feeder Design", "Coordinate Distance Calculation", and a "Feeder Design for Sylvania Amplifiers". Users of microcomputers are supporting this effort by contributing programs. And I thank them.

But most owners of microcomputers are searching for more programs. Like I said in the opening, the problem is the computer. It is fairly inexpensive to purchase, operate, and maintain. It almost seems too easy to do.

But this is part of the threat. The

computer is deceiving because it is only half there. The other half is the computer program. Besides articles in the trade press, there are few other places to turn for programs. This is the threat which may impede the development of microcomputers in this field.

No computer manufacturer is going to offer cable television software to this industry. The industry must develop the programs itself. Manufacturers have much to gain. They could offer programs which show how to simply design plant with their equipment. Or how certain equipment operates. Or how to properly adjust equipment. Both educational and useful programs are necessary.

Microwave and satellite earth station suppliers have much to gain by providing microcomputer programs. Designing and planning either type of station requires a variety of calculations to be performed. While programmable calculators can do some functions, microcomputers provide a better means to both explain the necessity of the calculation and make the computation. One company has an excellent program on a programmable calculator comparing the cost of various earth station equipment. Such a program on a microcomputer would be even more effective and would interest many owners.

An opportunity exists for any company or individual in the microcomputer field. An important part of any business is to be recognized as a leader in the field. With an excellent program, any manufacturer or person can easily gain an excellent reputation. For years they could be recognized as having the best program and this can add to their success.

THREAT TO ELECTRONIC DESIGN

Cable television is a vital part of the electronics industry. And as any casual observer knows the field advances quite rapidly. This industry is a leader in both satellite communications and optical fibers. Such new technolgy requires both the technician and engineer to constantly learn about new developments.

In electronics the vacuum tube was once king. With the advent of the transistor, tubes are used very little. And now integrated circuits, sometimes known as black boxes, are replacing transistors. But the most fundamental change is the microprocessor.

The microprocessor is part of the threat. Without the microprocessor, small computers like the Radio Shack TRS-80 would be impossible. They can substantially reduce the costs and size of electronics packages. They make the design of electronic products dependent on programs and very little on test circuits and soldering. This changes the way of doing "business" for most engineers and technicians.

For example, Cliff Schrock recently wrote an article about his "Blue Sky Box" in "Communications - Engineering Digest". "Security, Energy and Pay-Per-View", describes an elegant, flexible and relatively low-cost method of providing auxiliary services on a cable television system. Cliff states that "the real breakthrough in design cost and flexibility came with introduction of the single chip microcomputer." And all special services will be digital.

COMPETION WILL ATTACK WITH MICROCOMPUTERS

And this is a threat. Unless an engineer or techician has an appreciation for microcomputers, it would be very difficult for them to make such necessary services available on their system. For the industry to continue its progress technical personnel and owners must become aware of the microcomputer and its implications.

With the assistance of General Instruments, the parent company of Jerrold Electroncis, Matel Electronics, better known for their games, recently introduced their limited microcomputer called Intellivision. (What is television now stupivision?) There was much speculation in 1978 that Jerrold was going to introduce such a microcomputer to mate with cable television systems. Such a device is necessary.

In Europe, and on an experimental basis in the United States, the vertical blanking interval is being programmed. More information is being provided with that brief "time" in the television transmission than is available in most daily newspapers. It makes the "data" services provided on cable systems look amateurish. While it does require a special home decoder, its cost should be quite low when mass produced for the millions of U. S. television homes. This too is a use of microcomputers.

Several companies, including Digital Broadcasting in McLean, Virginia, and the Digicast Project in Calfornia, are offering or planning to offer computer services to consumers using broadcast facilities. It appears that if cable can not offer such "blue sky" services, the entrepreneurs are approaching broadcasters. The competion with broadcasters remains.

Microcomputers effect the future development of cable television. First, they threaten the present way of evaluating a cable television system, and technical personnel should be aware of this. Second, there is currently a lack of programs in the cable television field which threatens microcomputer development and provides an oportunity for companies and individuals. Third, it is important that microcomputers are understood because many new advances in electronics have them at the heart of their design. And fourth, the competion in this electronics industry is already starting to provide digital auxiliary services which has important consequences for cable television. In order to compete, technical personnel, managers, and owners must understand microcomputers.

POWER SUPPLY REQUIREMENTS AND VOLTAGE CALCULATIONS FOR CABLE POWERED CATV SYSTEMS

James K. Waldo

I am reminded repeatedly of how very basic and straightforwared calculating voltage drops and subsequent amplifier voltage inputs is. I have learned, that unless calculations are made on a consistant basis, though they are basic, aren't quite as straightforward to the average technician as one may think. If the Chief Engineer, Design Engineer or whoever is not familiar with how to calculate voltage drops and subsequent voltage inputs to the various amplifiers, the end result can be very costly. The following is an attempt to show and or explain how these calculations are made, so that the end result will be a well-designed power distribution system as well as a well-designed RF system.

Some basic rules of thumb will keep you in the ball park.

<u>30 Volt Systems</u>

1. Approximately two (2) trunk stations in both directions of the power supply with no more than three (3) extenders off of each one.

2. Minimum input voltage to an amp should not be less than 22 Volts AC.

<u>60 Volt Systems</u>

1. Approximately three (3) trunk stations in both directions of the power supply.

2. Minimum input voltage to amp should not be less than 45 Volts.

3. No more than three (3) extenders per trunk station.

These are merely rules of thumb that will do nothing more than get you in the ball park prior to the actual calculations. Do not use just the rules of thumb without actual calculations or you will get into trouble.

<u>Remember</u>: IR drop is the voltage drop in the cable preceding the amplifier and is equal to the total current associated with that drop times the loop resistance of that drop.

<u>Loop resistance</u> is defined as the resistance of a piece of cable shorted at one end and measured at the other between shield and center conductor. The unit of measure is in ohms. In manufacturer specs., it is usually given in ohms per 1,000 feet.

You must look up the loop resistance for the cable in your system. In the majority of our cable systems, constant current amplifier power supplies are used and the manufacturer's specs. can be obtained from the amplifier literature.

The current requirements are greater for amplifiers in 30 volt systems than for 60 volt systems.

Most modern day systems are built with 60 volt power supplies, as more amplifiers may be fed per power supply and surge immunity is improved.

The current state of the art amplifiers utilize what are called switching regulator type power supplies, whereas the current is not as constant as is the power. The Jerrold SJ amps are of this type. The manufacturer's specs. for these types of amplifiers gives the power requirements of each station. For the purpose of this paper, you are to utilize the average current given in the manufacturer's specs. in the described procedure for calculating IR drops.

EX: Model SJ-1 A trunk station, power requirements utilizing the SPCM switching regulator type power pack, is 31 watts (approximately .52 amps at 60 Volts).

The Starline One series amps utilize constant current power supplies, as do amplifiers utilizing the SPP-30 and 60 volt power packs. These are often referred to as constant current series regulator type power supplies.

Exhibit A will take you through the calculations for IR drops and subsequent input voltages to each amp for a 60 volt system utilizing Jerrold push pull amps with SPP-60 volt power packs.

Refer to Exhibit A

$E_{drop(A)}$ = I_T (total current required of amplifiers in Section Z) X

R (loop resistance of .750 cable between power supply and amp #3)

= 3.05 (amps) X .63 (ohms)

= 1.92 Volts

$E_{drop(B)}$ = I_T (total current required of Section X) X

R (loop resistance of cable between amp #3 & 4)

= 1.85 (amps) X 1.26 (ohms)

= 2.33 Volts

Amp #4 Voltage Input = Power Supply Voltage - $E_{drop(A)}$ - $E_{drop(B)}$ =

60 - 1.92 - 2.33 = 55.75 Volts

$E_{drop(C)}$ = I_T (total current requirement of Section Y) X

R (loop resistance of .750 cable between power supply and amp #2)

= 3.05 (amps) X .63 (ohms)

= 1.92 Volts

$E_{drop(D)}$ = I_T (total current requirement of Section W) X

R (dc loop resistance of .750 cable between amp #2 & 1)

= 1.2 X 1.26 = 1.51 Volts

Amp #1 Voltage Input = 60 - $E_{drop(C)}$ - $E_{drop(D)}$ = 60 - 1.92 - 1.51 =

56.57 Volts

Amp #3 Voltage Input = 60 - 1.92 =

58.08 Volts

Amp #2 Voltage Input = 60 - 1.92 =

58.08 Volts

After the Input Voltage to each trunk station has been established, IR drops for distribution lines are calculated and subsequent input voltage to each extender. Once input voltage to each trunk station has been established, it becomes the source voltage for all extenders off that trunk station.

Input voltage to each extender off a trunk station is then figured as follows:

Compute the IR drop for each extender in cascade off each distribution leg of the associated trunk amp, beginning with the furthest extender in cascade. Remember to add the required current of each preceding extender as you calculate IR drops towards the trunk amplifier. Input voltage to the furthest extender off a trunk amp is equal to the trunk amp input voltage minus the total of all IR drops in between the trunk amp and the furthest extender.

EX: Distribution leg with three extenders off of amp #4.

1. Figure IR drops first.

Extender "A" IR = .35 amps X 1.44 ohms

(2.4 X .6) = .50 Volts

Extender "B" IR = .35 amps X 1.44 ohms

(2.4 X .6) = .50 Volts

Splitter to Extender "C" = .7 amps

(I_A + I_B) X .48 ohms (2.4 X .2) -

.34 Volts

Extender "C" IR = 1.05 amps (I_A + I_B + I_C) X 1.56 ohms (2.4 X .65) = 1.64 Volts

Voltage Input Extender "A" = 55.75 Volts (voltage input to trunk amp #4) - 1.64 Volts (IR_C) - .34 Volts ($IR_{Splitter}$) - .50 Volts (IR_A) = 53.27 Volts

Voltage Input Extender "B" = 55.75 Volts (voltage input to trunk amp #4) - 1.64 Volts (IR_C) - .34 Volts ($IR_{Splitter}$) - .50 Volts (IR_B) = 53.27 Volts

Voltage Input to Splitter = 55.75 Volts (voltage input to trunk amp #4) - 1.64 Volts (IR_C) - .34 Volts $IR_{Splitter}$) = 53.77 Volts

Voltage Input to Extender "C" = 55.75 Volts (voltage input to trunk amp #4) - 1.64 Volts (IR_C) = 54.11 Volts

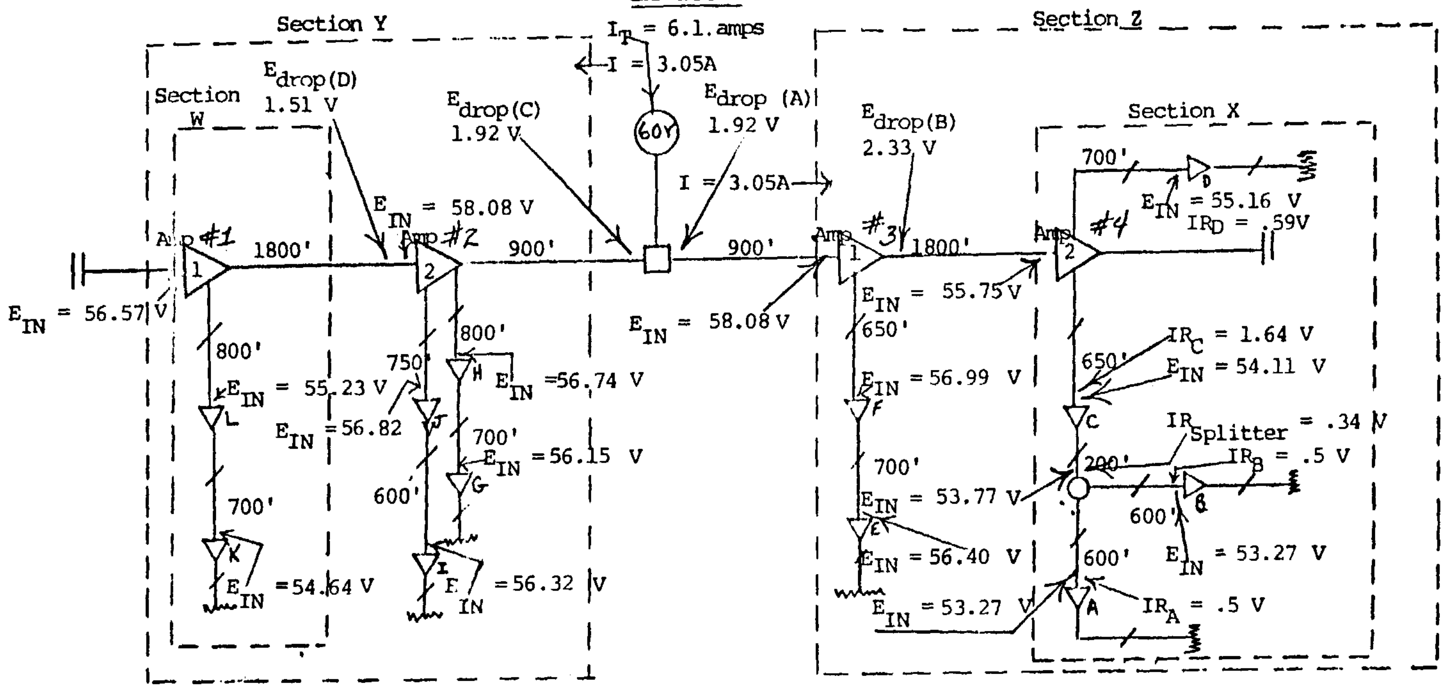
NOTE: For each leg off of a splitter, where line extenders are involved, IR drops are figured for each leg back to the splitter. Input voltage to the last extender off a splitter leg is calculated as shown above for extenders "A" and "B". Subtract all IR drops between the extender and the trunk amp, from the trunk amp input voltage. DON'T INCLUDE ANY IR DROPS OFF ANY OTHER LEGS OF THE SPLITTER!! These legs are calculated in the same manner as the one just described, excluding, of course, the IR drops of the other leg or legs of the splitter.

The same calculations may be used for 30 volt systems, only the current requirements of the amplifiers will change.

Total current drain of the main power supply is calculated by simply adding the current requirements of all stations off each power supply leg and then adding them togehter for the total. See Exhibit "A".

If there are any questions on this paper, please call or write me.

Exhibit A



Symbols

- .412
- .750
- SLE - 300 Extender
- Power Inserter
- Splitter
- Terminator
- SP-1 & 2 Amps
- Main Power Supply

Loop Resistance

.750 = .7 Ω /1000'

.412 = 2.4 Ω /1000'

Amplifier Current Requirements

SLE - 300	.35 A @ 60 V
SP - 1	.5 A @ 60 V
SP -2	.45 A @ 60 V

PREVENTATIVE MAINTENANCE OF SMALL SYSTEMS

RICHARD F. ROBERTS

COBB-CHEROKEE C.A.T.V.
ACWORTH, GEORGIA

Organization of scheduled preventative maintenance and operating practices minimize trouble calls. Prior to convicting subscribers of non-education of cable T.V. the knowledge of service offered and its quality must be understood from manager to installer level first.

Technical personnel are constantly haunted by the acceptable viewing and reliability of their system. Keeping this quality through scheduled maintenance of processing and distribution equipment, proper installs, effective service call response/ evaluation and continuing education can result in a reliable system.

The proficiency and congeniality of manage ment, marketing and engineering will reflect customer appreciation of the product they are purchasing.

Preventative maintenance and operating practices of a cable system regardless of size are as effective as the general practices governing the operation and self discipline of individual employees.

Discipline is the controlled behavior resulting from training intended to produce a specific pattern. This pattern refers to the activities related in the prevention of customer complaints and to the extension of the useful life of the cable equipment.

The knowledge of service offered, its quality, must be understood from manager to installer level prior to convicting subscribers of non-education of cable T.V.

Both aspects are important benefits gained from adherence to operating guidelines of a system. Resulting in less down time and better system performance.

Preventative maintenance is not confined to engineering alone. Management and marketing are also affected. Operating practices may not be appropriate to each individual and area of operations, but the two do interreact.

"The absence or neglect of a system maintenance program will result in an increase in subscriber complaints. Undetected minor problems and defective system components that do not cause outages or serious signal degradation accumulate, unless they are attended to, and "weaken" the system so that eventually a minor problem causes catastrophic failure or serious signal degradation. A well-maintained system will not normally result in subscriber dissatisfaction. For an example, a system with several dB reserve above the perceptable noise and distortion levels can often experience failure of the automatic slope/ gain function in one amplifier without effect upon subscriber satisfaction. Good system maintenance requires the detection and repair of this failure, however, to prevent a second failure from causing complaints. Periodic verification and maintenance of the "performance reserve" will also prevent such minor (non-catastrophic) failures from causing subscriber complaint.

Perhaps an even more significant benefit of a good system maintenance program is the extension of the system's useful life. Premature replacement of cable and electronic equipment due to lack of proper maintenance is commonly accepted as "unavoidable" in many CATV systems. The cable does not "wear out"..poor system maintenance practices allow it to become unuseable from preventable causes. Improperly formed expansion loops result in cracked sheath, center conductor pull-out, etc.; badly installed connectors and fittings permit moisture to penetrate the dielectric; inadequate clearance from trees and other obstructions permit physical damage. These circumstances are, of course, preventable, detectable, and correctable.

Electronic equipment, and in particular amplifiers, are also often prematurely replaced. The major reason for amplifier replacement has been directly, or indirect ly, related to the physical condition of the housing. In particular, the failure to properly seal the housing lid against moisture has been the most frequent cause of amplifier loss."

Headend maintenance requires regular attention to the antennas, tower, buildings and processing equipment in the same manner as the distribution system. Headend output levels should regularly be measured including all visual and aural carriers, pilot carriers, etc., and compared with the headend log to verify normal operation.

The accuracy and reliability of mechanical devices and instruments also require periodic monitoring and servicing as reccomended by the manufacturer.

Strict adherence of maintenance activities are considered necessary for the preservation of the company's property value, and also for the reliability and quality of subscriber service to gain and retain those subscribers! [1]

Quality service is marketable and marketing is also governed by general practices. Marketing comprehension of the systems technical capabilities and sales must not excelerate to the point that the technical support from sale to install and service becomes uncontrollable. A substantial time lag from sale to service degrades the community relations proportionally; just as unacceptable service to existing customers can.

Correlation of managerial, technical and marketing inputs to maintain an efficient operation is the discipline involved to ascertain the nature of customers problems and conducting them to concerned personnel or scheduling work requirements at appropriate times. Also familiarization with cable terminology to give information to callers, prepare reports, logs and correspondence in an appropriate manner must have its guidelines as the previous areas of operation.

The need for effective operating practices and maintenance programs; combined with the proficiency and congeniality of management, marketing and engineering; will reflect in profits and customer appreciation of the product they are purchasing.

Kleykamp, Gayheart C,
Director of Engineering
Norwalk Cable TV Construction

1. System maintenance practice 5-3, March, 1979. Norwalk Cable TV Construction, Norwalk, CT.

PROGRAM MANAGEMENT IN IMPLEMENTATION

Ernest O. Tunmann

Tele-Engineering Corp.
Framingham, Massachusetts

The application of Program Management in implementation of cable distribution systems is to be recognized as an important tool in the planning and controlling of the ever increasing growth of the cable industry.

Wether the turnkey contractor is a supplier, an independent turnkey implementor or an MSO running a Bill of Material implementation, the planning and control tools are identical.

The report describes Program Management Techniques used by TELE-ENGINEERING CORP. that have been specifically adapted to the implementation of cable distribution systems for the sole purpose to deliver highest system quality and on-time completion with minimum cost overruns.

1.0 Introduction

Any project that consists of many subsystems, products and product interfaces, relies on the wisdom and control of a Program Management Office to meet performance specifications and to assure an on-time completion without cost overruns.

What then is Program Management and how can it be applied to the implementation of Cable Communication Systems.

Tele-Engineering Corp. has adapted the most important program management techniques to cable implementation and utilizes these management tools effectively in all its turnkey programs.

2.0 The Program Office

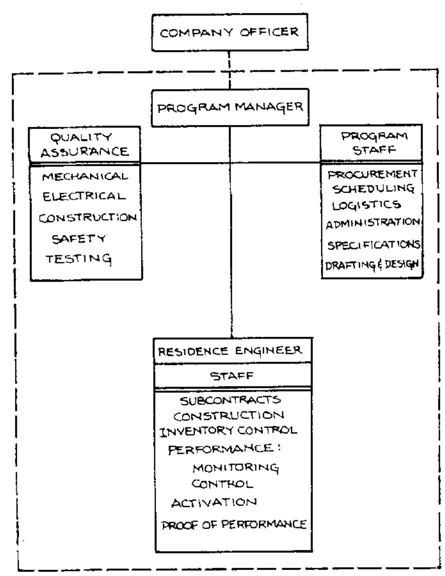
The Program Organization (Fig. 1) should consist of a balanced team of people skilled in

a) Cable system design and performance
b) Construction Practices, Outside Plant
c) Quality Assurance
d) Business Administration

For small projects, this knowhow may be concentrated in a team of two people. Larger and multiple projects may require three people per project that can pool their efforts through centralized business administration.

The Program Manager must be given full authority in the conduct of the daily business and must be held fully responsible for the progress through completion.

FIG. 1
PROGRAM MANAGEMENT ORGANIZATION



3.0 Program Management Techniques

Program Management Techniques consist of a set of management tools that permit accurate planning and control of all project activities from inception through completion of the project.

In order to effectively measure productivity and cost at any point in time during the implementation phase, it is of foremost importance to break the total project into measurable quantities, and to schedule both performance and cost expenditures over time.

Planning Tools in Program Management are:

a) Work Breakdown Structure
b) Work Order Numbers
c) PERT Chart
d) Monthly Cost Budgets
e) Monthly Performance Budget
f) Monthly Cash Flow

Control Tools in Program Management are:

a) Inventory Control System
b) Performance Reporting
c) Cost Collection System
d) Cost Performance Comparison
e) Remedial Activity Programs

Quality Enforcement Tools in Program Management are:

a) Quality Assurance Program
b) Safety Assurance Program

4.0 Project Planning

4.1 Work Breakdown Structure and Work Order Numbers

Most Projects, requiring system ingration, consist of the following four major categories:

Materials
Subcontracts
Labor
Expenses

The Work Breakdown Structure breaks these major categories down to logical subcategories. Even when the procurement of electronics and passives, or other combinations, will be made from a single source, the work breakdown structure of Fig. 2 is recommended to account for the timing of equipment deliveries in accordance with schedule requirements. To simplify cost control, it is also advisable to structure purchase orders and subcontracts in accordance with the breakdown structure.

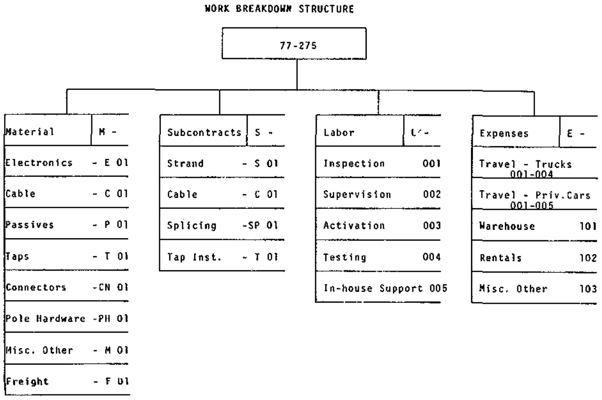
Devise a logical numbering system that establishes good recognition in the project control phase. A number like 15045A is quite meaningless. Establish a main project number, a subcategory number and an identifier.

Example:

78-358 -	M -	EH01
Project No.	Sub-category	Electronics, Housing, 1st purchase order

Fig. 2 shows an example of a Work Order numbering system ready for cost control and with total budget cost assignments.

Fig. 2
WORK BREAKDOWN STRUCTURE



4.2 PERT Chart

A PERT (Program Evaluation Real Time) Chart is the most important planning document for any multi-component project. PERT-charting organizes your mind to think in terms of activities that must be conducted in sequence or that can be accomplished in parallel during a given time frame.

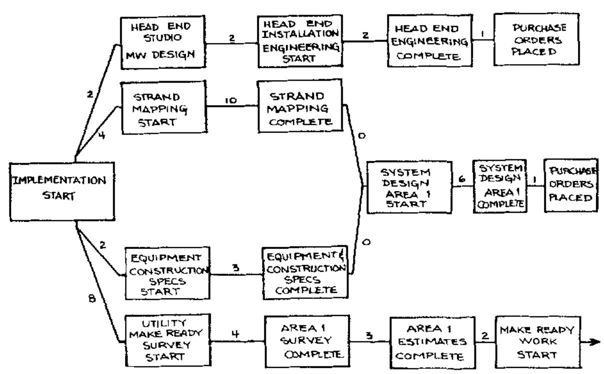
Fig. 3 shows a simplified section of a PERT Chart of a cable distribution system.

Your own ideas on the duration of a particular activity can be expressed in terms of (best) -normal and (worst) time intervals expressed in weeks.

In the preparation of your PERT Chart be fearful of the "uncontrollables" such as make-ready, highway permits, railroad permits, easements, anchors etc. Allow sufficient time to manage these events before construction start, rather than having to stop or slow down construction in the midst of the field activities.

Review the PERT Chart carefully, make changes and allowances at this time - you are determining all important milestones of the program and you want them to be met.

FIG. 3
PERT CHART
PRECONSTRUCTION ACTIVITIES



4.3 Monthly Budget Cost Assignments

Any material and labor item in the work breakdown structure can be assessed as to total costs and then spread over time.

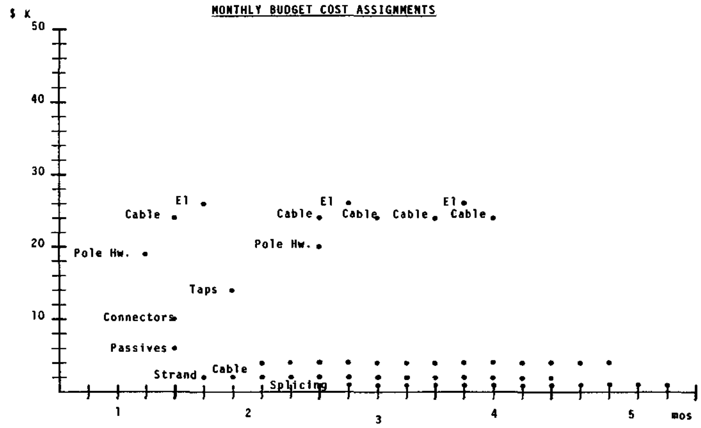
Using the PERT Chart as a guide, we know when we need certain materials. Large dollar items like electronics and cable can be scheduled for three or four shipments.

Fig. 4 shows a graphic presentation of cost expenditures over time for materials and construction activities.

Where budget cost determination over time for materials is simply scheduling of delivery dates, the scheduling and budget cost determination for construction and other labor tasks require a good knowledge of subcontractor ability, construction equipment and manpower.

Fig. 4

MONTHLY BUDGET COST ASSIGNMENTS



4.4 Monthly Performance Budgets

Fig. 5 indicates the performance curves of the stranding, lashing and splicing activities.

The slope of this curve is directly related to the cost per foot and to the time allotments per week.

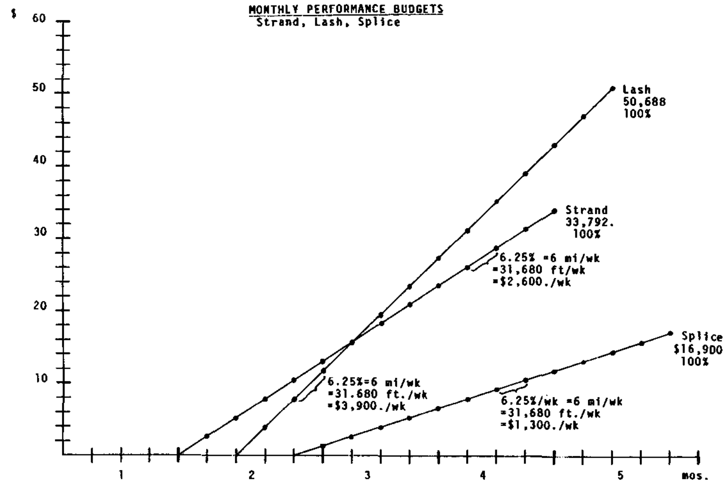
The example shows all three activities budgeted for 31,680 ft. per week. This kind of determination should only be made after an intimite knowledge of construction and splicing crew composition, equipment and manpower availability.

In case where you are working with outside construction companies, it is important to get proper commitments in writing before budgeting the weekly progress. What you are interested in is an average production output that assumes normal weather delays.

The slope of these curves becomes the baseline for progress-monitoring later in the program. It is, therefore, important to spent some time to determine the expected output per week.

Fig. 5

MONTHLY PERFORMANCE BUDGETS
Strand, Lash, Splice



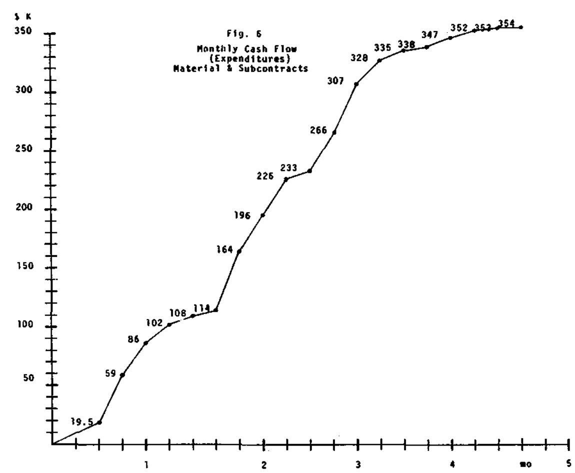
4.5 Cash Flow

Fig. 6 shows the month-by-month cash flow curve of the project. Indicated are only expenditures in order to determine cash requirements over time.

Customer payments or bank loans would reduce the cumulative buildup of cash requirements and determine actual interest and cash requirements.

The weekly cash requirements of Fig. 6 have been determined by adding the weekly components of Fig. 4 (Monthly Budget Cost Assignments) in a cumulative manner.

Since this curve indicates total expenditures over time for the particular project on hand, it can serve as an ideal tool to measure actual cost expenditures against plan throughout the program.



5.0 Project Controls

5.1 Inventory Control System

Shipments of materials and equipment to the project warehouse will have to be inventoried. The inventory control forms for incoming materials are grouped in accordance with work order numbers.

Separate forms, similar to Fig. 7, for pole line hardware should be available for incoming shipments of

- cable
- passives
- connectors
- taps
- electronics

Each inventory control form should contain the purchased quantities in the first column in order to identify full shipments as well as back orders.

At the end of each week all incoming material records are entered in the project inventory log book and the incoming material control forms are forwarded to the home office for comparison with vendor invoices.

Once construction has started, materials are being taken out by the strand crews, by the lashing crews, by splicers and by activation personnel.

Fig. 8 shows a typical material control form for strand materials. The form indicates columns for each day of the week and a weekly total.

The weekly total column is entered into the inventory log book every week and the material-on-hand column adjusted accordingly.

Similar forms are required to permit the monitoring of materials for lashing, splicing and activation.

A physical inventory of everything in the warehouse is taken every two weeks to compare with the on-hand column and to reveal any material shortages that may be unaccounted for.

Fig. 9 indicates the Inventory Control Summary. In addition, it is the residence engineer's duty to determine the requirement for any further material purchases from the physical inventory. This can be accomplished by comparing the rate of construction with the completion percentage and by extrapolation to project completion.

Fig. 8

TELE ENGINEERING CORP

Telecommunications Engineers and Contractors

CONSTRUCTION MATERIAL CONTROL Form #2201

STRAND CREW

PROJECT No.__________ WEEK OF_____

The following material has been provided to crew foreman for pole framing and stranding.

DESCRIPTION	QUANTITY MO	TUES	WED	THUR	FRI	SAT	TOTAL WEEK
1/4" Strand No. of reels							
" footage							
J25088 3-Bolt straight							
J7901A 3-Bolt curved							
J8810 10" Bolt							
J8812 12" Bolt							
J8814 14" Bolt							
J8816 16" Bolt							
J8050 10" Thimble							
J8052 12" Thimble							
J8053 14" Thimble							
J6510 Thimble Nut							
J8563 Nuts 5/8"							
J1074 Washers 2"							
GDE1104 Pref. Dead End							
GLS-2104 Splice							
Crossover Clamp							
J7920 Ext Arm							
Guy attachment							
K1 weaver clamps							
Copper staples							
#6 Bare Copper							

Date:__________

Crew Forman Initial__________

TEC Initial__________

Fig. 7

TELE ENGINEERING CORP

Telecommunications Engineers and Contractors

INCOMING MATERIAL RECORD Form #1101

POLE LINE HARDWARE

PROJECT No.__________

The following material has been received and all quantities verified. Copies of shipping documents are attached.

DESCRIPTION	PO# ORDER DATE____ ORDER QTYS.	INITIAL REC. DATE____ QTY. RECEIVED	INITIAL REC. DATE____ QTY. RECEIVED
1/4" Strand No. of reels			
" Footage			
Lashing Wire			
J25088 3-Bolt Clamp flat			
J7901A " " curved			
J8808 8"			
J8810 10"			
J8812 12"			
J8814 14"			
J8816 16"			
J8050 10" Thimble Eye			
J8052 12" " "			
J8053 14" " "			
J6510 Thimble Nut			
J8563 Nuts Square 5/8"			
J1075 Washers 2 1/4"			
GDE 1104 Preformed Dead End			
GLS-2104 Splice			
09010 D-type Lash. Clamp			
1602 Beatty 1/2" Spacer			
L891 10" Straps			
L892 16" Straps			
Crossover Clamp			
J7920 Steel Exr. Arm			
Treeguard 6 ft.			
#6 Copper Bare (ft)			
TCS-15-24 Heatshrink			
TCS-17-24 0.75 Heatshrink			
K-1 Bonding Clamp Weaver			
Copper Staples			
Tap Bracket			
Electrical Tape			
Silicone Grease			
Guy Attachment			
8" Screw Anchors			

Fig. 9

INVENTORY CONTROL SUMMARY

Material	1 Initial Shipments	2 (-) wk No.1	3 (-) wk No.2	4 Balance wk No.2	5 Physical Inventory wk No.2
Pole Line Hardware					
Cable					
Passives					
Electronics					
Taps					
Connectors					

5.2 Performance-Reporting

A properly devised performance-reporting system consists of the daily collection of completed footages for

- stranding
- lashing
- splicing
- activation

and a weekly compilation that is prepared by the residence engineer and forwarded to the home office.

The daily summaries (Fig. 10) are compiled on a weekly basis and the weekly total entered on the monthly performance budget curves for comparison.

Fig. 11 indicates the progress of stranding made over the first 2 months in a particular project.

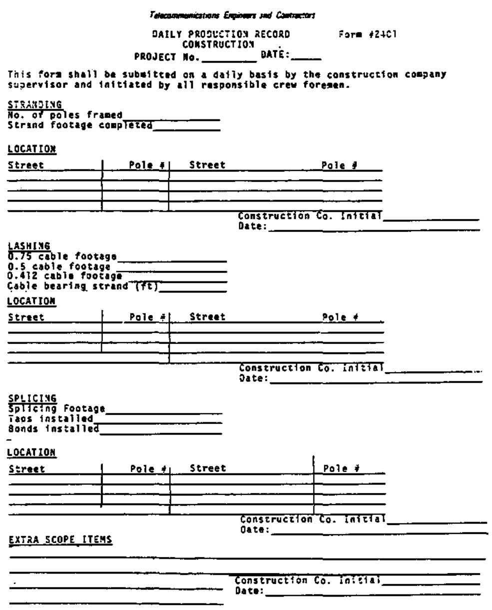
Fig. 12 indicates the progress of stranding made over the first 2 months in another project.

A quick glance at this type of presentation will give you the necessary insight into the actual production flow. It is now possible to determine slippages quickly, forecast schedule delays, facilitate remedial actions and, in a general manner, actively control the construction activities.

Cable lashing, splicing and activation can be monitored and controlled in identical manner or by Power Supply Areas.

Fig. 13 indicates a budget vs. actual comparison of activation performance by power supply areas.

Fig. 10


Telecommunications Engineers and Contractors

DAILY PRODUCTION RECORD Form #2401
CONSTRUCTION
PROJECT No.________ DATE:_____

This form shall be submitted on a daily basis by the construction company supervisor and initiated by all responsible crew foremen.

STRANDING
No. of poles framed__________
Strand footage completed__________

LOCATION

Street	Pole #	Street	Pole #

Construction Co. Initial__________
Date:__________

LASHING
0.75 cable footage__________
0.5 cable footage__________
0.412 cable footage__________
Cable bearing strand (ft)__________

LOCATION

Street	Pole #	Street	Pole #

Construction Co. Initial__________
Date:__________

SPLICING
Splicing Footage__________
Taps installed__________
Bonds installed__________

LOCATION

Street	Pole #	Street	Pole #

Construction Co. Initial__________
Date:__________

EXTRA SCOPE ITEMS

Construction Co. Initial__________
Date:__________

Fig. 11
Project No: A
STRAND CREW PERFORMANCE

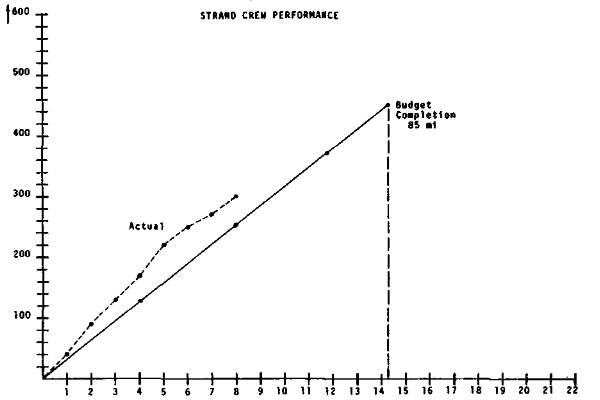


Fig. 12
Project No: B
STRAND CREW PERFORMANCE

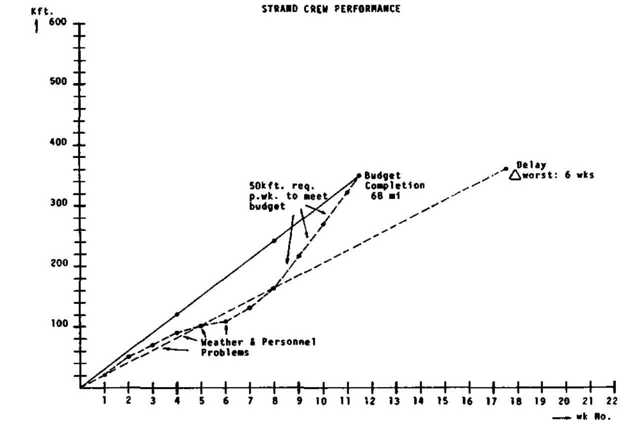
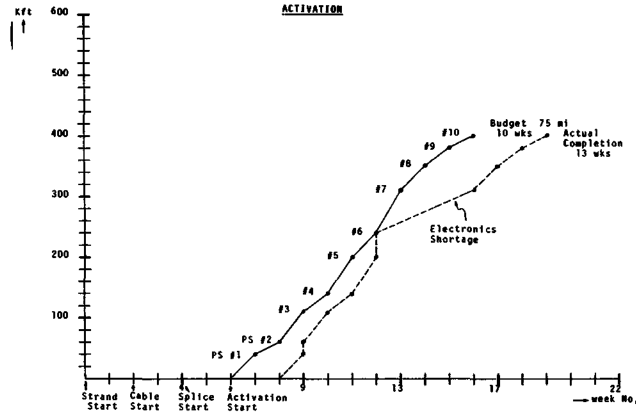


Fig. 13
Project No: C
ACTIVATION



5.3 Cost Collection System

The work order numbers and associated budget cost amounts form the baseline of the cost collection system.

Project planning has already determined the project cash flow and the monthly or weekly expected expenditures in each category.

It is now important to collect vendor invoices for materials, subcontractor invoices for construction, and labor and expense records of your personnel in a systematic manner.

Fig. 14 shows the Project Cost Summary with sample entries for stranding and labor.

The form should be prepared for total budgets of all work order numbers and with the appropriate budget entries for month No.3.

Actual costs incurred through month No.3 are now entered and compared to the budget.

It becomes apparent that stranding costs are under budget by $ 4,400.-, which means that the stranding operation is late. On the other hand, supervisory labor and activation is overrunning the budget.

The cost-to-complete estimate indicates that stranding will not overrun at the end of the project, but we can draw the conclusion that completion will be delayed.

Vendor and subcontractor costs must be incurred in accordance with budget to keep a project on target.

Supervision and activation labor shows a total budget variance of $3,500.- and takes recognition of the fact that construction will be late and that supervision and activation periods have to be extended.

These two-line entries tell the whole story:

a) Completion will be late
b) Cost overruns are being incurred

The project cost summary cannot provide any information as how much delay will be incurred. Inputs from the performance-reporting are required to get the full picture. It is also possible to update Fig. 6, the Monthly Cash Flow presentation, by plotting the Total of the column entitled "Actual Cost to-date".

Fig. 15 shows the first 3 months of costs cumulative plotted over time. The actual cost expenditures indicate that the project is $ 102,000. underspent and 4 weeks late.

The reason for this can be late deliveries of equipment, late invoicing, construction delays etc. It is time to take a closer look.

Fig. 14

PROJECT COST SUMMARY

Project No. 77-275 Month No. 3 Week No. 13 Date ______

Work Order Nos.	Total Budget	Week No. 13 Budget	Actual Cost to-date	Present Variance (-) +	Cost to Complete Estimate	Total Budget Variance (-) +	Reason for Change
S - S01	31.7	23.8	20.3	(3.5)	11.4	0	Crew/Weather
L - 003	18.7	10.8	12.2	1.4	11.4	4.9	Eqmt. Probl.

* enter total on Monthly Cash Flow TEC 77-275

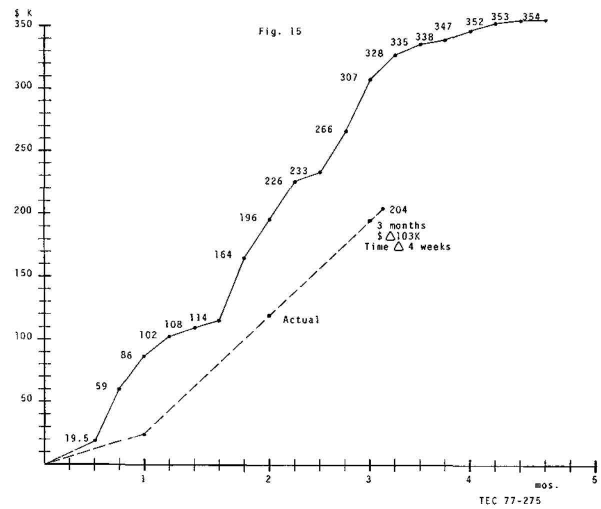


Fig. 15

5.4 Cost/Performance Comparison

First, it is important to analyze all entries in the Project Cost Summary.

Fig. 16 shows a summary with completed entries. A large portion of the cost underrun is caused by late material deliveries (about $ 90,000.). The rest is due to late construction. A review of the strand and cable crew performance curves would show that the construction is about 2 to 3 weeks behind schedule.

The project cost summary also indicates positive cost variances in the labor area for inspection, supervision and activation.

These are caused by equipment problems and, indirectly, by the extension of the construction activities.

The overall conclusion that can be reached is that the project will be completed four weeks late and that it will cost $ 11,000., or about 2.6% more than it was originally estimated.

The importance of remedial action cannot be stressed enough. Late completion is costly to the turnkeyer and the operating company. A four week delay of completion may mean a substantial revenue loss of installation fees and monthly rates.

Fig. 16

Project No. 77-275 PROJECT COST SUMMARY

Work Order Nos.	Total Budget	Week No. 13 Budget	Actual Cost to-date	Present Variance △(-) +	Cost to compl. Estimate	Total (Budg. Variance △(-) +	Reason for Change
M - E 01	65.0	65.0	30.5	(34.5)	34.5	-	Late Delivery
- C 01	88.5	88.5	42.2	(46.3)	46.3	-	Late Delivery
- P 01	7.5	7.5	7.5	-	-	-	
- T 01	26.3	26.3	16.3	(10.0)	10.0	-	Late Delivery
- CN 01	13.2	13.2	13.2	-	-	-	
- PH 01	39.0	39.0	40.2	1.2	-	1.2	Add. Requirement
- M 01	4.5	4.5	3.5	(1.0)	1.0	-	
- F 01	3.0	3.0	3.5	0.5	0.5	1.0	Higher Costs
S - S 01	31.7	23.8	20.3	(3.5)	11.4	-	
- C 01	47.5	23.8	16.5	(7.3)	31.0	-	
- SP 01	15.8	6.7	5.4	(1.3)	10.4	-	
- T 01	12.6	5.8	4.8	(1.0)	7.8	-	
	354.6	307.1	203.9	(103.2)	152.9	2.2	
L - 001	8.6	6.5	6.8	0.3	2.3	0.5	Equipment Problems
- 002	10.5	5.0	6.8	1.0	7.2	3.5	Late Construction
- 003	18.7	10.8	12.2	1.4	11.4	4.9	
- 004	12.5	6.5	5.2	(1.3)	7.3	-	
- 005	6.5	3.5	3.0	(0.5)	3.5	-	
	411.4	340.2	237.9	(102.3)	184.6	11.1	

5.5 Remedial Activity Programs

In the last paragraph, we have tried to explain the interdependency of deliveries, construction performance and costs.

It has become apparent that even short delays in material deliveries can cause long delays of the project completion date and incur substantial cost overruns.

Remedial actions have to be harsh to offer relief. There is no time to waste.

Here are some of the steps that can be taken, sorted by degree of the magnitude of the problem:

a) Late Deliveries
- request shipment by air
- request partial shipment
- request critical items shipment
- find substitute supplier and supplement
- cancel order after finding substitute supplier who will deliver on time

b) Late Construction
- request to add manpower to construction crews
- request additional strand lashing crews
- supplement construction with 2nd construction company
- set deadline for production improvement and change construction companies

c) Late Splicing
- request additional splicer
- supplement splicing by employing additional independent personnel or company employees

The applicability of any of the above remedial procedures depends upon the circumstances at hand. Whatever the decision may be, it must be made within the shortest possible time frame and it must assure a higher production rate than originally budgeted.

6.0 Quality Control Tools

6.1 Quality Assurance Programs

The quality of the implementation program has to be safeguarded throughout the life of the project.

Quality Assurance measures have to be structured and timed in accordance with the progress of all activities:

a) Incoming Inspection
b) Construction Inspection
c) Splicing Inspection
d) Activation Records

Forms for good record-keeping of these tasks shall be developed to assure conformance to all construction and performance specifications, and to assure a distribution plant that requires minimum maintenance.

6.2 Safety Assurance Programs

Safety can only be stressed in a general sense as part of this presentation. It is truly a topic by itself and much too important to be treated lightly. Too many accidents have already happened in our industry that could have been avoided, had proper precautions been taken.

The residence engineer must be a safety-minded individual and enforce the following ground rules:

a) Construction Crews
- placing of "men working" signs
- placing of safety cones
- use of beacon on trucks
- use of hard-hats
- use of safety vests
- use of gloves
- use of a running ground during stranding
- flag man
- state or local police details on heavily traveled roads

b) Power Companies
- tree-trimming in primaries
- fast remedial response in cases of hot street light brackets, bare secondaries, broken neutrals, and other electrical shock hazards.

It is recommended that the residence engineer devotes at least a few minutes every day to enforce the safety rules with the construction crews. Habitual offenders should be warned and removed if required.

7.0 Summary

This presentation has tried to explain the importance of program management in the implementation of cable distribution systems.

Our industry has sufficiently matured not to tolerate badly run turnkey projects that are not planned properly and that cannot be controlled to guarantee an on-time completion.

Even if it is not possible to prevent all delays, it is essential to apply the proper tools to minimize delays and maximize the quality of our product.

Both the turnkeyer and the operating companies must recognize that a few dollars per-mile spent for planning, control and quality assurance will go a long way to minimize cost overruns, loss of subscription revenues and maintenance expenditures.

It is time to take a look at our mistakes in the past, remove the "low-bidder-will-do-it-somehow" principal and insist on accurately planned program implementation already in the proposal phase, so to assure timely completion and quality system performance through proven program management techniques.

RELIABILITY - A TOTAL APPROACH

By Don Dworkin, Ellery Litz, Peter Parikh and Harry Suri

Just as reliability within an individual equipment, for example an amplifier, is the multiplied product of the reliabilities of the separate components, so the reliability of a CATV system, as far as the customer is concerned, is the product of the reliability of every equipment in series with the siganl path - from antenna to the television set.

Further, in line with the customer's point of view, reliability must be defined as the steady production of a good quality picture, and any operation below that standard, whether due to ice or co-channel at the head-end, excessive hum or power outage in the system, or drifting of a converter at the subscriber must be counted as a failure.

This article will discuss system reliability from this point of view using both theoretical and system history to illustrate. Still existing deficiencies will be identified, the overall object being to firmly establish a totally service- and system-style of thinking and work in regard to CATV reliability.

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New York, NY 10019

Complete text is either printed in appendix B or available upon request from the author.

ABSTRACT

SATELLITE CROSS POLARIZATION

Satellites that utilize 24 Transponders and 12 Transponders that are horizontally polarized and 12 Transponders that are vertically polarized. Care must be taken to ensure that the Earth Station is properly aligned to keep the Transponders from interacting with one another.

This paper presents principals behind the changes that occur in the received polarization direction and suggests the appropriate times for making polarization adjustments. Faraday rotation and rain depolarization are considered, as well as satellite position and antenna pointing error.

In addition to the theoretical analysis of depolarization, practical methods for aligning antenna feeds are presented.

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Home Box Office, Inc.
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SIGNAL LEAKAGE FROM CABLE SYSTEMS AND POTENTIAL INTERFERENCE TO RADIO SERVICES[1]

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Federal Communications Commission, Washington, D.C.

and

Jean E. Adams
National Telecommunications and Information Administration
Boulder, Colorado

ABSTRACT

Due to the possible hazard to air navigation that might be presented by leakage from cable television systems utilizing aviation frequencies, the Federal Communications Commission formed a committee to investigate how best to prevent a problem. Numerous airspace and ground based measurements were conducted in an attempt to correlate air and ground leakage fields. The methods employed for these tests and preliminary conclusions of the authors are contained in this paper.

1.1 Background

In 1977 the Federal Communications Commission adopted interim rules designed to prevent interference to aeronautical radio services by signal leakage from cable television systems. The rules require that cable operations be offset in frequency from any aeronautical radio service operating in the neighborhood of the cable television system.[2] Shortly thereafter, a cooperative research program was initiated to determine the conditions, if any, under which cable television systems could safely operate on the same frequencies as nearby aeronautical radio services. Participants in the program include the Commission, the Federal Aviation Administration, the National Telecommunications and Information Administration, and representatives of the cable television industry and private aviation interests. Initial results of that research program are presented in this paper.

The susceptibility of navigation receivers to cable signal interference was addressed in studies performed by the U.S. Department of Commerce Office of Telecommunications.[3] Results were given in terms of signal to interference ratios, where the interfering signal had to be offset from the navigation signal by very precise frequency differences.

In the case of existing communications receivers, a convenient reference point is the power level at which the squelch control is set to open, although this level is not necessarily the only criterion for interference. The most sensitive of todays receivers may have squelch set at -97 to -101 dBm[4] input to the receiver. Most receivers are less sensitive, and probably have squelch set at a level higher than -97 dBm.

It is not possible to say exactly what the interference susceptibility of tomorrows receivers will be. It is reasonable to assume that many will be digital, and therefore probably less sensitive to interference. But of course, one must not make plans for cable leakage limits on such an assumption. Therefore, no assumptions about interference susceptibility of future receivers are made here.

1.2 Objective

The principal objective of the research was to determine how to predict fields in the airspace from measurements made at ground level. Three methods of ground measurement were used, and several parameters of the airspace fields were considered. Rank order correlation coefficients between the ground measurements and the airspace measurements were used to determine whether or not the objective was achieved.

---

1 Opinions and conclusions expressed in this paper are those of the authors and do not necessarily represent the views of the National Telecommunications and Information Administration, the Federal Communications Commission, or its Advisory Committee on Cable Signal Leakage.

2 Report and Order, 65 FCC 2d 813 (1977).

3 Electromagnetic Compatibility of Simulated CATV Signals and Aircraft Navigation Receivers, OT Report 74-39 (Tom Harr, Jr., et al., 1974); Flight Test Measuring Compatibility of Simulated CATV and VOR Signals, OT Report 75-75, (John R. Juroshek and Tom Harr, Jr., 1975); and Radiating Aerial Coaxial Cable Measurements, OT Report 75-73, (Tom Harr, Jr., et al., 1975). Available from the National Technical Information Service, Springfield, VA 22151.

4 dBm: decibels relative to one milliwatt.

1.3 Assumptions and Conditions

Two principal assumptions were made in order to simplify the research program to manageable proportions:

(a) For a given leakage source, the power radiated is reasonably independent of frequency; and

(b) The effect of radiation patterns of individual leakage sources can be neglected.

The first assumption is reasonable on theoretical grounds, since the physical size of cable leaks (millimeter dimensions) is small compared to wavelengths at the frequencies in question (108 - 400 MHz). The second assumption is reasonable in cases where the number of leaks in the cable system is large (the only case of real concern), since in that case an average of whatever radiation pattern exists, would be observed both on the ground and in the airspace.

It was desired to examine cable systems of a range of sizes, ages, and types of construction. A total of 12 cable systems were chosen for the measurement program.[5]

A pilot signal at 118 MHz was imposed on the cable system for all airspace measurements reported here. The convention of setting the power level of that signal equal to whatever peak power level the cable operator normally used for the visual carrier closest in frequency to 118 MHz was adopted. Since the test signal was unmodulated, its rms power would have been around 4 or 5 decibels higher than that of a visual carrier having the same peak power. Thus the test signal would have been 4 to 5 decibels higher in rms power level than a typical visual carrier which might be carried in the VHF aeronautical radio band (108 - 136 MHz). On the other hand, signals at the higher frequencies are carried on cable systems at levels perhaps seven decibels higher than corresponding signals in the 100 MHz range. Thus, our signal may have been as much as three db or more below the rms power level used in the aeronautical radio band 225 - 400 MHz.

5 The twelve cities were: Atlantic City, NJ, Arlington, VA, Bridgeton, NJ, Coatesville, PA, Hagerstown, MD, Harrisburg, PA, Independence, MO, Leavenworth, KS, Pottsville, PA, Raytown, MO, St. Joseph, MO, Salisbury, MD. Further reference to individual cities will generally be by letter code only, since our objective was not to publicize characteristics of individual systems but to correlate measurement techniques over a wide range of systems.

2. AIRSPACE MEASUREMENTS AND ANALYSIS

2.1 Single Frequency Measurements

The airspace data reported here were collected on magnetic tape at the rate of 200 power level measurements per sencond as the aircraft flew a predetermined grid pattern at a given altitude. Average speed was about 275 kilometers per hour, giving several samples per wavelength.[6] Altitudes flown were approximately 450, 1500, and 3000 meters above average terrain of the city. The receiver used had a half-power bandwidth of about 400 Hz, operating at the same frequency as the test signal on the cable television system. A spectrum analyzer display centered on 118 MHz served to constantly confirm the presence of the cable leakage signal. Tests were made using both horizontal (navigation) and vertical (communication) receiving antennas. The antenna giving the higher level response -- the vertical antenna -- was used to obtain the data reported here. A separate test indicated that cable radiation appears to exhibit no particular polarization.

An inertial navigation system was used to determine aircraft location at any given instant, anticipating detailed mapping of the signal level in the airspace. However, analysis of strip chart displays of data shows that only rather crude maps could be made. Signal levels generally rise reasonably smoothly to a maximum over the city, then fall of as the aircraft leaves the cabled area.

2.2 Data Analysis

Reduction of the data -- points numbering in the millions -- was done in four ways: (a) frequency distribution plots, (b) cumulative distribution plots, (c) calculated means and standard deviations (in a few cases) and (d) strip chart recorder plots (in a few cases) for visual inspection.

The frequency distribution plots were most useful for differentiating among signal characteristics which were common to all or most runs and therefore most likely due to cable systems, and characteristics which occurred only occasionally and therefore were likely due to signals from other sources.

Cumulative plots were most useful for correlating ground measurements with airspace measurements, since median signal levels as well as 10th and 90th percentile levels were readily obtained from these plots.

6 The aircraft was a Convair 580 twin engine turboprop.

3. GROUND MEASUREMENTS AND ANALYSIS

3.1 Measurements

Ground-based measurements were made by three different methods: (a) a dipole antenna and a Field Intensity Meter (tunable voltmeter) were used to measure field intensity approximately 3 meters from the cable at all discovered locations where field strength was over 50 microvolts per meter; (b) meter scale readings of a commercially available "leak detector" designed for cable television use were recorded whenever a relative maximum was observed as a vehicle was driven past the cable; and (c) the same equipment used in the airspace measurements was used to record power input to the receiver every 240 millimeters[7] as the vehicle followed cable lines. All three measurement methods utilized a pilot carrier on the cable, in the same manner as the airspace measurements. A vertical whip antenna was used for methods (b) and (c). The commercial leak detector was reset to the same sensitivity for each run by means of an internal calibrator.

System-wide results from the field intensity meter and the leak detector correlated surprisingly well, even though the leak detector scale is highly non-linear near the top end. Therefore, an "absolute calibration" of the leak detector was made by comparison of leak detector meter indications with field intensity meter results. Then the two sets of data were combined for some of the correlation analysis presented in Table I.

3.2 Analysis

In order to identify a single parameter of the ground measurements for correlation with airspace measurements, various "leakage indices" were calculated from the ground data. Given the electric field strength E_i for all leaks i measured 3 meters from the leak; R_i, the slant height from leak i to a point H meters above central point in the cable system, and ϕ, the fraction of the cable system actually covered by the ground crew; a leakage index I_H may be calculated:

$$I_H = \frac{1}{\phi} \sum_i \frac{E_i^2}{R_i^2} .$$

Obviously, the estimation of ϕ could be a significant source of error.

If I_H is calculated for low altitudes it is possible that the arbitrary choice of the "central point" over which the index is calculated might be fairly critical. The index would be rather heavily weighted toward the situation directly under the point chosen. Therefore, the index calculated at an assumed height of 3000 meters was preferred for our analysis.

7 The distance information was provided by an accurately calibrated "fifth wheel" attached on the vehicle.

Calculation of the R_i from maps is tedious. In order to see whether a simpler calculation would be acceptable for routine cable operator use, an index I_∞ was calculated without the use of slant height:

$$I_\infty = \frac{1}{\phi} \sum_i E_i^2 .$$

These indices I_∞ correlated with airspace measurements just as well as the more "intuitively correct" I_{3000}.

In the case of the automated ground data, recorded with the narrow band airspace receiver modified for ground use, the logarithmic mean (mean of the power received, expressed in dBm) was used as the leakage index I_{avg}.

4. RESULTS

Rank order correlation between airspace and ground data was calculated using the following expression[8]:

$$r_s = 1 - \frac{6 \sum_{i=1}^{n} d_i^2}{n(n^2-1)} ,$$

where d_i is the difference between the rank of cable system i when ranked according to one measure of leakage and the rank of the same system when ordered according to the second leakage measure being compared, and n is the number of cable systems in each of the lists being compared. The correlation coefficient r_s can assume values between -1 and +1, where +1 indicates perfect correlation.

Table I summarizes these correlation results. We see that the three methods for ground measurement correlate with each other remarkably well, given the many possible sources of error in all three types of measurement. Of course, in cases where only 3 or 4 data sets are available the correlation coefficient could change significantly with additional data.

The correlation of airspace data at 450 meters with airspace data at 3000 meters is high, but definitely not perfect. This probably reflects the detection of more non-cable sources of noise and interference at the higher altitudes.

8 Statistical Methods, G.W. Snedecor and W.G. Cochran, 6th ed., The Iowa State University Press, Ames, Iowa (1967).

The real test comes, however, in the correlation of any one of the ground measurements with any one of the airspace indications of cable system leakage. The highest correlation with ground measurements is obtained from the median (50th percentile) or the 10th percentile of the airspace measurements made at the lowest altitude -- 450 meters. It is not at all surprising that best correlation should be obtained at the lowest altitude, because of the potentially higher noise fields and interference sources detectable at higher altitudes, especially over major metropolitan areas. The frequency distribution plots probably give the best clue as to why the correlation with the 90th percentile level is not so high. Those plots show significant numbers of rather sharp (narrow spread along the power axis) peaks. These peaks are apparently unrelated to cable leakage, since they are not consistently present from one run to another. They are probably other interference sources. They distort the cumulative distribution curves near the 90th percentile level more than at other percentile levels, because they appear more often at or above the highest levels of the distribution of cable signal leakage power.

Correlation coefficients are given both for data sets including and not including City F. City F was dramatically and consistently worse in terms of ground/air correlation than any other city in our set. Typically, City F would appear 10th in the ranking (decreasing order of signal) according to airspace measurements, but around 4th in the ranking by ground measurements. This anomaly is unexplained. But at least it can be said that if the ground measurements are in error, they erred on the "safe" side by giving City F a higher leakage rating than it apparently deserved on the basis of actual airspace measurements. The improvement in correlation coefficient when City F is not considered is given in the far right column of Table I.

Finally, we note that the correlation among all leakage measures was quite high in the case of the city with the highest airspace signals. That city was the only one in which both of the following conditions held: (a) both airspace and ground measurements were available for correlation, and (b) airspace signals at the 90th percentile level would clearly have opened squelch circuits on a modern communications receiver. That city appeared at the top of the list (highest leakage index) in every case -- all airspace measurements at any altitude and any percentile measure, and all ground leakage indices which were calculated.

5. CONCLUSIONS

At the time of this writing, the formal committee report has not been released and no Commission action has been taken; however, there are several possible conclusions. Some of those conclusions may be:

1) To accept the current frequency offset requirements as being the most reliable solution;
2) To adopt the position that ground measurements are sufficient to assure that no air hazards are presented;
3) To require airspace measurements;
4) To prohibit use of midband or superband frequencies by cable systems; or
5) To relax current standards.

The adopted procedure will undoubtedly not be a clear-cut solution, but will either be some combination of the above or some yet undefined conclusions.

6. ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions of all committee members and researchers, but especially the following deserve special recognition:

Jean Paulson (ITS) - Reduction of automated data.

Eldon J. Haakinson, Robert E. Phillips and Thomas A. Harr, Jr. (ITS) - Construction of automated equipment.

Ed Sawtelle, James Dong and NAFEC staff (FAA) - Aircraft and measurement equipment.

The full cooperation of participating cable systems is also appreciated.

TABLE I

RANK ORDER CORRELATIONS

Rank Order Set 1			Rank Order Set 2			Correlation Coefficient		Number of Items in Rank Order Sets		Correlation Improvement when City F is Removed
Space	Percentile	Altitude (meters)	Space	Percentile	Altitude (meters)	with City F	without City F	with City F	without City F	
AIR-GROUND										
Air	90th	450		I_∞		.56	.67	10	9	.11
Air	50	450		I_∞		.67	.90	10	9	.23
Air	10	450		I_∞		.62	.83	10	9	.21
Air	90	3000		I_∞		.26	.42	8	7	.16
Air	50	3000		I_∞		.38	.60	9	8	.22
Air	10	3000		I_∞		.40	.59	9	8	.19
AIR-AIR										
Air	90	450	Air	90	3000	.79		10		
Air	50	450	Air	50	3000	.83		11		
Air	10	450	Air	10	3000	.71		11		
GROUND-GROUND										
I_{3000} (Field Intensity Meter)			I_{3000} (leak detector)			1.00		3		
I_∞ (Combined FIM & leak detector data)			I_{3000} (Combined FIM & leak detector data)			.99		10		
I_∞ (Combined data)			Automated ground data			.80		4		

SMALL EARTH STATIONS
Protection of Service

Robert H. Allen

Rockwell International

This paper examines the protection of programming and service for the small earth station for the Cable Television Business.

A review of the CATV Companies and the growth of the business over the last few years shows that the availability of new programming sources has produced industry growth. A quick examination of what is available in the programming area is provided. This growth has and will continue to require more equipment to handle the added service.

A discuss of protection of programming and service is provided. This includes some block diagrams of service protection techniques used with discussions of each. The techniques covered include schemes for protection of low noise amplifiers, video receivers, polarities, power etc. Protection of programming is discussed briefly. Techniques used are controlling the satellite video receiver via clock, telephone, in-band switching, out of band switching, micro-processor control.

1.0 Introduction

The technology advances in the past few years have brought satellite communications to a reality. More recent advances have brought the cost within the reach of the cable television industry. With the advances, the quality and quantity of the service has increased tremendously. The protection of service and programming is paramount to management of a cable system. This protection is divided into two areas: the first is the protection of the service and the second, protection of the programming.

Recently RCA has announced the launch of a third satellite because of predicted business . Their "Cable Bird" (Satcom 1) is almost saturated with programming. Earth stations having more than five video receivers are becoming commonplace. The need for wide band cable system is here and the programming is available. A problem in using the programming available is that the common carriers, RCA, Western Union, etc. typically rent/lease a channel for a certain number of hours per month. Most contractors do not specify which transponder (channel #) or satellite. Thus the service can be moved around and the Earth Station operator must be flexible.

Not all of the program originators have rented the channel they use on a 24 hour a day basis. This allows the common carriers to rent this channel to another programmer during other hours of the day. Since most cable operators hardwire their Satcom recievers to a cable television, modulator, most transponders are distributed to the public 24 hours a day. The FCC has stated that the cable operator is responsible to squelch the output of video receivers picking up unwanted signals (Programming). That is the cable operator must distribute only programming he is authorized to distribute. This can be done by retuning the video receiver to desired programming or by turning off the receiver or suppressing the output of the receiver or cable modulator. No matter what vehicle is used the cable operator is "responsible" to insure that he distributes only programming he is contracted to receive.

Expanded program availability has led to multichannel earth stations making protection schemes important to the smooth operation of a cable system. FCC requirements placed on cable operators compels interest in Program Protection schemes.

2.0 The Cable Television Market

Cable Television had its early start in providing video programming to areas without the benefit of commercial television. This was done by high quality reception of distant TV stations, and/or microwave of video programming, and/or coupled with the bicycling of video tapes.

In recent years the cable television market has blossomed into a thriving business. Technical advances combined with the FCC approval of 4.5 meter antennas have provided economical earth stations which are profitable for even the smallest of cable systems. Additional programming and services distributed via satellite combined with the entrepreneural aggressiveness of cable operators has spawned a phenomenal expansion of the cable television market.

Currently, the cable market reach some 20 million homes with a variety of services. Cable systems are being installed in major metropolitan areas because it is becoming profitable in almost all communities. Cable television franchise are being applied for in most communities at an increasing rate. These indications point to projections that cable will reach 80 million homes by 1984.

The technology of space (Satellite) communications and the availability of good video programming are both responsible for the boom in the cable business. The technology is here to stay but the quality of programming could be subject to degradation. But this author feels that with the quality and diversity of programming in a free market place there will be an improvement in programming to which the public will benefit. The programming available today is in the form of end movies, HBP, Fanfare, ASN, super stations: WGN Chicago, WTCI Atlanta, etc, News and weather via audio subcarriers (slow scan video), Christian broadcasting: PTL, CBN, Trinity broadcasting and special events.

The special events range from Fanfare and Hughes sports to Robert Wold, to PBS, to SIN. Some of the special events are for broadcasters only,but cable can use them on a "non-interference" basis which will become more attractive as the cable systems continue to expand. Remember cable systems have multi channel capacity while broadcasters are limited to one channel. These multi channel capabilities of the cable systems require multi sources. As the market grows, cable system operations will continue to grow in size and complexity. Techniques discussed in this paper provide some solution for service protection of multi channel satellite earth stations.

3.0 Protection of Service

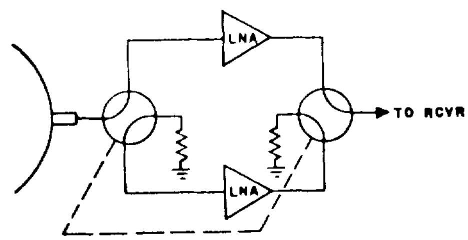
The most important thing in the cable business is the (uninterrupted) distribution of programming to the customer. Obviously, cost has a lot to do with the amount of redundancy and spare equipment on hand. But the protection of service is foremost in the minds of the cable companies.

A discussion of some redundancy of equipment follows.

Low Noise Amplifiers for Earth Stations

The Low Noise Amplifier (LNA) is a key element in the satellite earth station. There are three types of LNA's, but for the smaller earth stations used for video reception, the solid state (transistorized) will be the one disucssed here.

Most of the earlier/more expensive earth stations had redundant LNA's; redundant LNA's being defined as a 1 for 1 hot standby. That is, two LNA's and a waveguide switch mounted at the antenna. There are two good techniques for "switching LNA's". The first is the detection of a failed LNA from a fault indication, which is a summary alarm generated internally by the LNA. This requires a small amount of logic to determine whether the failed LNA is on line or not. If the failed LNA is on line (active), the waveguide switch should switch in the other LNA; otherwise, do nothing.

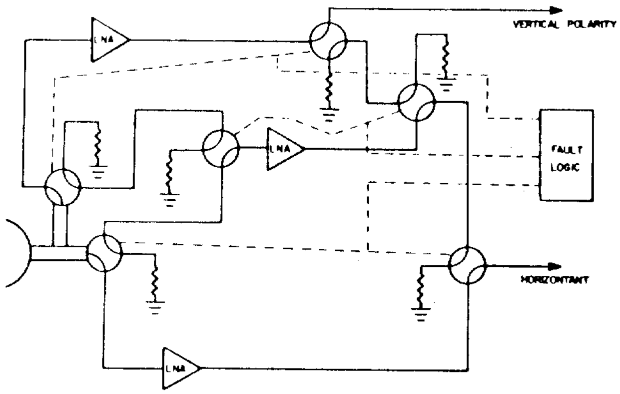


1:1 LNA SWITCHING

This method allows this LNA switching to be remoted by the use of a dry contact very easily.

The second method is to monitor the fault output of all of the video receivers. If all the receivers have a fault (loss of RF) simultaneously (within one second), then generally one of two things has happened. First, either the satellite failed, or there was a failure in the LNA. If the satellite failed, it does not matter what you do. If the LNA failed, then the off line LNA (standby) should be switched on line. This method is not as popular as the other method. It will become even less popular because the widespread use of both polarities on the RCA satellite require more effort to implement.

To carry this discussion of LNA protection one step further, if protection of two polarities is required, what is the best method? The trend for earth stations with reasonable access time seems to be to go with single LNA's for each polarity used and to have a shelf spare. Then,upon failure, a technician can change out the device in about 15 minutes. For a focal point feed mounted LNA, this can be longer. Earth Stations using dual polarities and requiring protection, i.e., hot standby LNA, the thought of using one LNA to protect two LNA's for each polarity has come up repeatedly. A diagram of how this could work is provided.



1:2 LNA SWITCHING

The cost of an extra waveguide switch, special plumbing (waveguide bends), and extra logic/cable would cost more than full redundancy for each polarity. A suggestion made frequently is to utilize full redundancy on the polarity where the majority of revenue producing traffic is, and use a signal LNA on the other polarity.

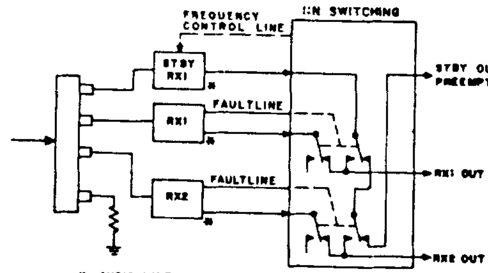
This provides 50% chance of protecting the

This provides 50% chance of protecting the failed polarity and if the single LNA dies per chance, then all is needed is to manually swap the hot standby with the failed LNA, thereby restoring service.

Video Receivers

The protection of radios in general has historically been by having more radios than required, so that a failed unit can be swapped out or relieved of its assignment. Critical assignments have required one for one protection of radios; that is, one hot standby protecting the on-line radio. The need to protect more than one radio, coupled with the cost of a video receiver, has caused the development of a one for N switch to be used with satellite Earth Station video receivers.

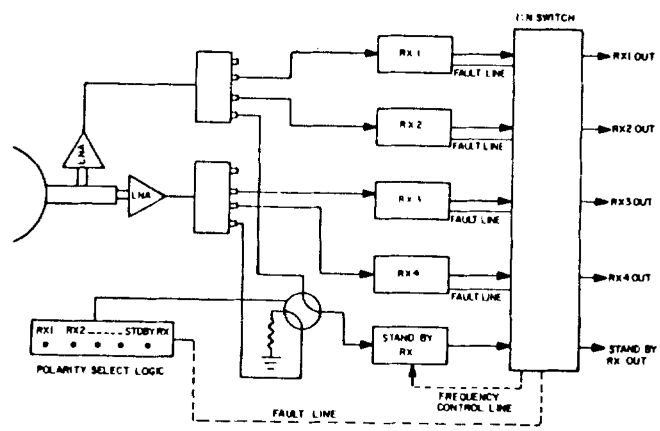
This baseband switch allows one frequency-agile video receiver to be the hot standby radio for more than one on-line receiver. Two companies making a switch are Scientific Atlantic and Collins/Rockwell International. They are one-for-seven and one-for-eight switches respectively. The block diagram shows a one for N switch used with a single polarity Earth Station. The block shows two on-line receivers with a hot standby.



* AUDIO LINES FOLLOW SIGNAL PATH (NOT SHOWN)

1:N RECEIVER SWITCHING

This protection of receiver can be carried a step further. The previous discussion was for multiple receivers on one polarity. But the switch can be used to protect multiple receivers on two polarities. The figure below shows a dual-polarity system with two receivers on each polarity, with the standby receiver receiving its RF signal from a coax switch that selects the RF signal from the same polarity as the receiver that fails. This additional function requires some manually programmable logic. The polarity select logic requires that the polarity of each reciever be set. This allows the polarity select logic to position the coax switch so that the standby receiver receives the correct RF signal (vertical or horizontal). Communication Properties Inc. has installed approximately fourteen of these dual-polarity video protections setups in their cable television earth station.

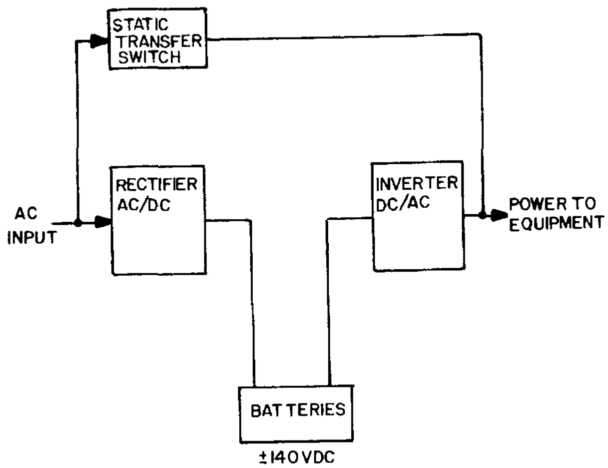


DUAL POLARITY RECEIVER PROTECTION

Communications Properties has also installed two antennas at their Midland, Texas, Earth Station location. The antennas and equipment are used as two separate systems, but for purposes of economics one could use any assortment of antennas, LNA's and one to N receiver protection schemes to best suit his requirement for protection of service.

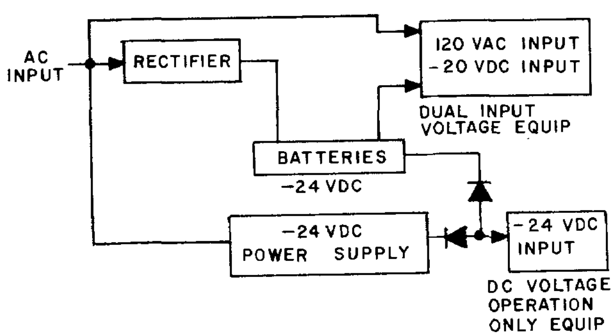
Power

There are many techniques for providing uninterrupted power systems (UPS) for communications equipment. There are three popular techniques shown. The first is typical UPS for large systems which provide an uninterruptable source of A.C. power. D.C. supplies are powered from the A.C. source. This is very expensive and generally not needed for video type reception (CATV type video).



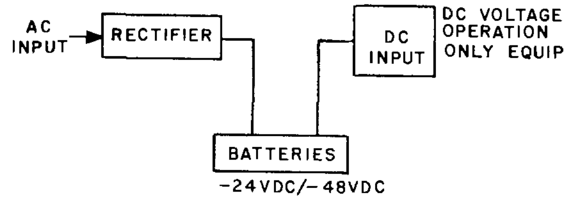
TYPICAL UPS SYSTEM FOR LARGE EARTH STATION
CAPACITIES RANGE FROM 10 KW TO 500 KW

The second type is the DPS with D.C. backup which holds down the size of the invertor (which is the largest cost element) and allows the D.C. powered equipment to operate off the battery!



TYPICAL UPS SYSTEM FOR SMALL EARTH
STATION WITH DC BACK-UP

The third type of system shown is the ideal situation where all equipment is D.C. operated. This is the most economical and most reliable type of backup.



TYPICAL POWER SYSTEM FOR MICROWAVE SYSTEM
OR SMALL EARTH TERMINAL

The diagrams do not point out than an emergency generator can be used in conjuction with all the techniques to compliment long power outages. However, as one cable operator implied, it doesn't do much good to have emergency power at the earth station/Head-in if the cable distribution system is also having a power failure. This is especailly true in smaller communities.

Telephone

The telephone is an excellent real time tool for changing channels on a video receiver or turning the programming on and off. Some of the PBS Earth Stations capability on their remoted earth stations. Other Satcom users have discussed this capability, but to date it is not in widespread use. One reason is that it requires someone to monitor all broadcasts and actually make the equipment changes real time.

Signals Contained in Programming (Out of Band)

Some of the program originators have agreed to put test tones on subcarriers as "trailer" to end of their daily programming. This would trigger a "switch-off" of the video receiver or a change in the frequency. An example of this would be that at the end of a movie, a special test tone would be put on the aural subcarriers for a period of time. This would be detected and cause the receiver to tune to another source of programming (like CBN or PTL) which allows 24-hour use of the equipment at a minimum cost for programming.

Signals Contained in Programming (In Band)

The other type of switching via transmitted signal is In Band switching. This is information contained within the video information that is picked out and used to control the video receiver. For example, Holiday Inn has requested that their upcoming 300 Earth Stations have information contained In Band that would control the frequency (channel) being received. This would be done by having the uplink source (program) put the information required in the programming for change to the next program source. The next source would be responsible for returning the receivers to the original channel moving another frequency. This would be done in concert with the program sources.

Microdyne reports that Microdyne, Scientific Atlanta, Holiday Inn, Home Box Office and RCA will perform tests to determine the best In Band technique for switching the Earth Stations video receiver frequency. By best method, we mean the best for Holiday Inn's application. Their opinion is that digital information on the vertical internal will allow the most latitude and be the best choice. Tests are scheduled for late April 1979.

Microprocessor control of the Earth Stations is immeninant. The widespread application of microprocessors has brought this technology within the reach of the small cable operation. The capability to fulfill numerous tasks is well within the capacity of the microprocessor. Examples of these tasks are:

- o Control Frequency of video receiver by the time or signals rec.
- o Control protection or redundancy of equipment.
- o Monitor Security.
- o Monitor ambient temperatures.
- o Control heating and cooling.
- o Interface with telephone to receiver command inputs or provide complete status of the Earth Stations and/or cable headin.

Program Coding

There is increasing requirement to secure that transmission of video programming. This requirements for both satellite and cable transmission.

ITT Space Communications has announced a Gray scale Sync Video processing system. This system is for improving signal to ratio, multiplexing audio channels into the video and implementing secure video transmission by switching the polarity of the alternate video scan lines. This has good potential and could be required to receive satellite transmission within two or three years. Because this would allow the programming houses like HBO, Fanfare, etc. to secure the transmission of their product, thus insuring that only subscribers receive the programming.

A less sophisticated technique which is perfect for cable distribution is the strip sync technique. Magnivox now sells a unit that strips the sync from the video programming and transmits the sync via a pilot carrier. The customer then installs a very inexpensive (CATV provide) demodulator at the input to his TV receiver which takes the sync information the pilot camera and inserts it back into the video information.

Conclusion

There are no such techniques of providing failure free service. There are many fine techniques of providing redundancy and control of equipment.The best solution to your operational needs must be determined by you. This includes consideration of cost, maintenance, equipment life, and others. A suggestion is made that consideration for protection schemes be made as you build or expand your systems. Most reputable equipment suppliers can help with solutions for protection, if not then system suppliers like Scientific Atlanta or Collins/Rockwell International will gladly assist you in selecting a protection scheme for your system.

SMALL SYSTEM PROBLEMS

Larry Loftin Searcy

Enterprise Cable Television, Inc.

ABSTRACT

In a small system, the problems encountered are many, but all could fall into three categories. These being (1) equipment, (2) personnel, and (3) management.

Equipment problems could be the most common, but also the most difficult to deal with. Another problem is the lack of adequate test- and maintenance equipment.

Personnel can be the number one problem if experienced and trained people are not employed. This could be the downfall of many systems whether large or small.

The third most common small system problem is management.

All of the above mentioned problems have varying ways of being solved. This paper will discuss some of these problems and their solutions.

TEXT

Equipment problems could be the most common and also the most difficult problems to deal with. In some small systems, especially if they are an older system, the equipment may be outdated by todays standards. If the system has not kept up with the modern innovations and ideas that have happened in our industry, then the service to its customers will not be the best it could be. Any system, whether it be large or small, must stay up with the modernization that is happening everyday. For example, who would have thought, three or four years ago, that an Earth Station would be available for almost any cable system in the United States.

Modernization is one thing that every system must keep at the head of its list of things to do. The amplifiers of five years ago cannot meet the specifications of amps that are produced today. With the new hybrid chips that are common today, amp spacing can be longer, with even better signal to noise ratio than was possible a few years ago.

Our industry is changing so fast with new and improved equipment being sold everyday. We must stay up with it to give our customers the best service we can.

Also, in small systems, the repair of defective equipment has to be accomplished by sending it to an outside company. This being the case, you would have three sets of equipment. The one you are using, the one on the way to the repair center and the one returning from the center. If a person could be employed that could repair the systems equipment, the savings would be tremendous. Also, this employee would be a better trouble shooter if he knew what malfunctions within the equipment caused certain problems. By repairing the systems amps, he could see from looking at the pictures on his longest trunk run and determine from that if all the amps are working correctly.

Another problem could be the lack of adequate testing and maintenance equipment. The most common is the field strength meter. The field strength meter, to us, is like a stethoscope to a doctor. With an adequate field strength meter, almost any problem within our system can be detected. To us, the field strength meter is our right hand man. Each system must have at least one, if not more, that is correctly calibrated for that systems operation. No system can operate without a good field strength meter. In our system, we keep a 7270 field strength in our head-end. This meter does not leave our head-end except for proof-of-performance measurements. This meter is the calibration standard for all of our other meters, and if any questions about accuracy occur, then this is the one that is considered to be right. If you use a different meter to set your line amps, and another one to set your head-end, than these should be calibrated at the same time to assure accuracy. We at Enterprise Cable Television calibrate all of our field strength meters every month. We make notations of any errors found, the date this was performed and the readings found. At the same time that we calibrate our head-end or trunk-amp meters, we also calibrate our installers meters. This is something that must be checked. The installers meters must be kept in the same operating condition as your line and head-end meter. I also believe that every truck within the system should have its own field strength meter and that this meter should stay with that truck at all times. At one time, we did not have a meter on each truck, but after a year of trying to share a 727 between two technicians, we soon solved that problem. At one time, we did not have installers meters, but we found that by giving each installers truck a meter, we soon saved the cost of the meter in drop cable that was needlessly replaced. Don't get into the habit if you have a trouble call, whether it be cross-mod or snow, of replacing the drop.

By training our installers to use their meters, the times that a technician has to be called has been reduced tremendously. The first thing that out installers do when they call for help on a trouble call is to tell us what the meter reading is. Not only the reading in the house but at the distribution cable as well. Our installers save us much time by not only knowing what the readings should be but why they should be a certain value. One very important point about meter readings and signal level is that to get a correct output, you must have a correct input. That is one thing that we at Enterprise Cable Television have learned through experience. No amplifier of any make can work like it's supposed to unless the input is right.

To a small system, another piece of equipment that may seem to be a luxury, is some form of radiation detection. Although radiation detection may seem like a waste of time and money, it can save on three important things: (1) trouble calls, (2) "might-be" customers, (3) keep you out of trouble with the FCC and FAA. If you have radiation within your system, it can cause problems to your paying customers, such as ghosts, intermittant good-to-snowy pictures and other kinds of picture degradation. Radiation is the leaking from your system the information being carried by your cable. If a person could pick up this leakage for free, why should he pay for it? Radiation detection may be a luxury, but it will pay for itself.

Personnel can be the number one problem if experienced and trained people are not employed. This one problem could be the downfall of many systems, including large and small. The person employed by a small CATV system needs to be a jack-of-all-trades. From an installer to main line trouble shooter. But how can a small CATV system afford to employ a top-notch technician or engineer? This is something that only the local manager or owner could answer. Here's a suggestion. At the NCTA National Convention in New Orleans last year, there was a session on CATV employees: Buy them, steal them, or grow your own. The consensus of opinion at that meeting was to grow your own. Who would know better what condition your system is in, or the inputs and outputs of each amplifier that the local tech who has grown up in that system. A good place to secure a technician is at the local Jr. College if they have an electronics program. This person would have all the book learning he would need, but he would have no practical experience. This could be an advantage because he or she could be trained in the way you would want your technician trained.

A good technician is only as good as the installers and trouble-shooters under him. A good installer may not be as hard to find as a technician, but he will have to be completely trained. As far as I know, there are no schools for installers. At this point, I would like to say that I feel that we, in our industry, need to start having some seminars for the local installer, even if we have to start by saying, "This is an F fitting."

We, at Enterprise Cable Television, have what we call rainy day classrooms. If we have a rainy day or an installer catches up with his work, he can always go to the head-end and pracsetting amplifiers and reading a field strength meter. Thank goodness that all of our installers can read a field strength meter and set any amplifier in our system. We accomplished this by setting up a test amplifier set-up in our head-end. This set-up includes a power supply like they may see out on the line, a main line or high level amp and a line extender. With this we can simulate any real situation within our system.

Employees need to be good public relations people for their respective companies. Each employee, from office personnel to chief technician must treat each customer with courteous and efficient service. Good public relations is one criteria that all cable systems must meet. One bad employee in a system can cause more harm than a two to three hour outage during a football game. There is an old saying that I remember that goes something like this, "The customer is always right." Up to a certain point, I believe that this should be a motto in our industry. We are unique in our field that we provide a service to our customers right in their homes. Our pictures, so to speak, are the proof of our work. If we provide a good quality signal with fast, dependable service, then the customer has received his moneys worth. On the other hand, if our picture quality is poor with service calls being handled very slowly, if at all, then we don't give the customer what he is paying for.

If a customer requests a service or trouble call, then that should be handled as expeditiously as possible. A good goal to set is to try as much as humanly possible, to go to that persons house during that same working day. We at Enterprise Cable Television give trouble calls number one priority. When a customer asks for service to them, the problem they are having is extremely important. Although sometimes it may be no more than a fine tuning problem, to that customer it is a major problem. It is especially important that all trouble calls be handled with good public relations. When your service man goes out to handle a trouble call, no matter how unimportant it may seem, he must listen intently to the problem and try to give a correct solution. We, in this industry, are human and we will make mistakes. If a problem is ours, I think we should admit it. But if the problem is not ours, then inform and show the customer why it is not our fault.

Another important point is not to try and snow our customers. If you don't know what the problem is, say so. But don't leave it there, assure the customer that you will consult with your system technician or engineer or that you will call someone within our industry for help. All of the suppliers of amplifiers that I know of always have someone at their office that you can talk to about technical problems. A customer who really wants to have good service will work with you and will wait a reasonable amount of time for a solution. A customer whose trouble was handled professionally and in a quick manner is a satisfied customer. Also, if he happens to tell a neighbor about the way you treated him, then this will be more good advertising for your company than a full page newspaper ad. Conversely, if he is not handled professionally, rest assured he will tell his neighbors.

Public relations is something that every cable system must keep up. A good working relationship with your customers will keep the amount of service calls down and give you the joy of knowing that your system is one of the best.

The third most common small system problem is management. Management could be a problem, but most times not. Usually the manager is also the owner. Therefore, he will be doing his best to make the system as good as possible. The person who is the manager needs not only to be a leader of his personnel, but sometimes a Dear Abby, too. At one time or another, an employee may have a problem that does not come within the scope of his job. He may need to do nothing more than just talk to someone about it. This is where the manager can set up a relationship with his employees that will benefit everyone within the company. A person cannot do a job better than the way he feels that day.

A manager must keep up with the problems that an employee encounters on and off the job. I don't mean to say meddle in his employee's private lives, but if his advice and consultation are asked for, he should have some knowledge of the situation. I think that the manager should feel that the employee is doing him a favor by working for him, instead of the manager feeling he is doing the favor. I feel a good manager is one of the prerequisites for a good system.

All of the above mentioned problems have varying ways of being solved. One of the best ways would be to have a continuing program of education for system personnel. From this, equipment can be up-dated, repaired and maintained. Personnel can be trained and advanced within the company. Management can stay ahead of system problems and solutions.

Continuing education is something that I think we will be hearing more of in the future. Our industry is a fast changing one with new and innovative ideas happening everyday. We must stay up with these changes to give our customer the best service possible. I applaud the Society of Cable Television Engineers in their efforts to have technical meetings throughout the nation. Not only does SCTE bring together the best speakers that can be obtained, but also it gives us, the technical and management personnel, a chance to come to together to discuss our problems with each other. Also, the NCTA has done a marvelous job in this respect at the convention last year in New Orleans. They presented discussions in every phase of cable communications.

I believe fully that all system problems can be solved by conscientious people doing their best as if they, themselves, were the customers.

ABSTRACT

SPECTRUM ANALYZER AS A COMPUTERIZED "PROOF OF PERFORMANCE" MACHINE

This paper presents the use of a programable spectrum analyzer as a computerized "Proof of Performance" machine, particularly for proving turnkeys where accurate rapid checking of system performance is of considerable economic performance. The system is described using a computer, plotter and high speed printer. In addition, a special van for the instrument is being specially fitted with power, air conditioning, etc. The van also has a two-way radio to provide an automatic data link back to the head-end so that the computer can instruct programmable signal generators temporarily installed at the head-end to work with the whole system.

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Complete text is either printed in appendix B or available upon request from the author.

SPECTRUM ANALYZER AS A COMPUTERIZED "PROOF OF PERFORMANCE" MACHINE

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ABSTRACT

The new Hewlett-Packard 8568A spectrum analyzer and associated computer controller and peripherals have been applied to the problem of automated field testing of cable television systems. The automated spectrum analyzer reduces testing time per test point from more than one hour to about 5 minutes. The test program emulates manual testing methods, but future development is expected to develop more optimum testing strategies. The system will be most valuable for testing new systems built under turn-key contracts and for technical audit of systems, particularly in cases of change of ownership. It is expected that automated video waveform testing will be introduced within a year.

The spectrum analyzer is now widely used and accepted as an important electronic instrument in cable television applications. Their principles of operation are now widely understood and various models are in use in the cable television industry in both field and laboratory application. They function as a form of "swept-display signal-level meter", presenting a comprehensive view of signal amplitude as a function of frequency. The first laboratory class instruments suitable for cable television work were introduced by Hewlett-Packard about 1970. This spectrum analyzer system was described, along with a number of cable television applications, in a paper which I presented at this convention in 1971. Similar laboratory class analyzers were introduced by Tektronix a few years later. Field type portable analyzers were later introduced by Texscan. Both laboratory and field type analyzers are now widely used in the cable television industry.

The versatility and precision of the laboratory type spectrum analyzers, particulaly the H-P and Tektronix models have made them popular for precision field television systems. Although I have referred to these analyzers as "laboratory" instruments, they can and are successfully used in the field, although their size, weight and power requirements means that they are somewhat restricted in their mobility. We have specially constructed, shock mounted cases for taking our laboratory type analyzers into the field - usually in a van with an engine driven AC generator system for power.

We have used laboratory class analyzers, both H-P and Tektronix, since they first became available. They made possible a class of measurement versatility and precision previously unavailable. A new generation of spectrum analyzer - exemplified by the HP 8568A system - is now available further expanding the utility, flexibility and precision of spectrum analyzers in cable television applications.

THE H-P 8568A SPECTRUM ANALYZER

The 8568A was made available by HP in 1978. It's principle distinguishing features include:

- use of digital processing and display of the video signal
- use of synthesizers for generation of local oscillators
- full programmability of all instrument control functions, using digital instrument keyboard, three internal microprocessors, and external HP-IB digital control bus
- compatibility with external computers, printers, plotters and other digital and analogue peripherals
- significant improvement in specifications over previous generation analyzers.

The 8568A tunes the 100 Hz to 1500 MHz range with synthesizer precision. It offers 10 Hz resolution throughout that tuning range. Tuning stability and phase noise are exceptional, and represent a considerable improvement over previous generation spectrum analyzers. It offers a spurious free dynamic display range of better than 85 dB with 100 dB displayed on the screen. It has a high quality flicker-free display with versatile alpha-numeric titling, further enhanced by the ability to reproduce the display on attached digital plotting and printing equipment. It has excellent internal self-calibrating features and above all is fully programmable. It is the programmable feature that appealed to us.

The 8568A functions can be programmed from a variety of external computer systems. The HP 9825A desk-top computer is most commonly used. H-P makes a variety of "library" programs available for using the 9825A as a controller for the 8568A and sells the complete system as the 8581A Automatic Spectrum Analyzer. We couldn't afford the 8568A as a "manual" spectrum analzyer, i.e. without the computer controller and preipherals. We feel that the cost of the analyzer is best justified when operated in an automatic mode.

APPLICATIONS OF AN AUTOMATED SPECTRUM ANALYZER

Automated test equipment has become very popular in manufacturing operations where an automated instrument set can be programmed and employed on a high volume production line with obvious economies. Such automated test sets perform complicated test routines automatically and accurately. We are not in the manufacturing business and we had other applications in mind when we bought our automatic spectrum analyzer system.

As a consulting firm providing support to several MSO's we have had extensive experience in proof-of-performance testing. We have two laboratory type spectrum analyzer systems (one each by H-P and Tektronix) that we employ nearly full time in such applications. We find that an experienced field engineer will take about one hour per test point to check a 20 channel system. It takes somewhat longer to check a system carrying more channels. Additional time is required in the office to interpret the field notes and 'scope photographs and to prepare the report sheets for each point tested. It takes a fair amount of experience and skill to run the instrumentation through all the tests required and to make sure that observations are accurately noted. We wanted to automate most of this process.

The easiest way to appreciate the degree of programmability of this analyzer is to study the manufacturer's operating manual or to participate in an actual demonstration. Center frequency, sweep width, reference level, etc. are all selected by digital keyboard. IF bandwidth, video bandwidth, and sweep time all adjust themselves automatically to maintain valid displays. All these parameters can also be individually controlled if desired. To put it briefly - control is provided, whether by keyboard or externally programmable, for virtually every operating parameter that the operator might wish. The analyzer also provides features not available on previous generation spectrum analyzers. There is a "max hold" mode in which the display updates only when the value is higher than previous sweeps. There is an automatic "video averaging" mode in which successive sweeps are arithmetically averaged and displayed. There is a "delta marker" mode in which the difference in both level and frequency between two markers is displayed. There are three digital memory storage arrays. Display data can be transferred between them and between analyzer and external computer.

These functions can be better appreciated by reviewing the digital video signal handling. The basic spectrum analyzer functions are performed in "analogue" mode. The analyzer is a triple conversion receiver, using synthesizers as local oscillators. After detection the video signal is converted to digital form by means of a digital/analogue converter. The display functions are then handled in digital form. The display consists of a 1000X1000 point array which is refreshed from memory at about 60 Hz rate. The 1000X1000 point memory array is managed by internal microprocessors which feed the video and sweep data into the array. These display arrays can then be "averaged", "added", " subtracted", printed out, plotted or handled in any other "digital" way that we may wish.

The digital video signal handling allows the instrument to perform such usefull functions as averaging and "max hold". It also provides fast "noise measurement" since it automatically performs the noise-bandwidth adjustments and calculations providing direct readouts in terms of level normalized to 1 Hz bandwidth. The computer controller then makes easy extrapolations to any other noise bandwidth, e.g. 4 MHz, that we wish.

Measurement units are also easily adjusted. Pushing a couple of buttons (or a simple computer command) changes readings instantly from dBm to dBmv to mv, and introduces the compensation for any external matching devices which are required. Vertical display scales are similarly changable from 10 db to 5 db to 2 db to 1 db per division.

Consideration of the specifications and operating manuals, and a bit of direct experience soon convinces one that this instrument under computer control can do anything a field engineer can do with a manually opoerated spectrum analyzer - better, more accurately and much faster.

Consideration of operating speed should be tempered by the fact that this is still an analogue instrument up to the video detector and it is subject to the same trade-offs of bandwidth, span and sweep time as are conventional spectrum analyzers. A sweep requiring narrow bandwidth and wide span still requires considerable time even when the sweep has been commanded digitally and the display is being read out and handled digitally. These sweep times become the limiting factor in system operating speed and are kept in mind when programming important consideration is that a complete display represents about 1 megabit of data and takes appreciable times to read in and out of the analyzer and occupies considerable external storage space.

With these advantages, and within the constraints we have briefly described, we have programmed our system to automatically perform a "proof-of-performance" test, printing and plotting the results automatically. We have generally emulated ther manual operation as a first generation approach top the required program. With some further field experience we expect to refine the program and technique, optimizing the procedure to take full advantage of this particular instrument system. The system first asks what tests and procedures are to be run, reads in external data such as names, date, location, etc. It then performs all the tests required, printing out directly, or storing information in digital form for later read-out. Sample displays and print-outs are appended to this presentation. We hope to provide an actual demonstration with the oral presentation of this paper at the convention.

ADVANTAGES OF AUTOMATIC TESTING

We believe that the main advantage of the automatic testing for cable television is speed. Added precision and clarity of data presentation is a valuable secondary feature.

The speed of operation (about 5 minutes per test point) is not necessarily a great advantage if there are few test points to be done and if there is a significant travel time between test points, as in the periodic testing to FCC or DOC requirements. These government requirements can be met by the testing of relatively few points and with a degree of precision adequately provided by less costly and complex instrumentation. Our principle interest in developing and applying this automated system is in proof of new turn-key contracts and in internal technical audit of operating systems.

Turn-key contracts are detailed technical contracts involving large sums of money and a complicated technical "product". Contractors are anxious to have their product accepted by the purchaser and receive their money. The purchaser is anxious to receive the system in the condition and to the specification contracted for so that he can begin business and startearning revenues just as soon as possible. An automated testing system allows a much larger number of test points to be checked to specification and at lower cost than is possible with the present manual testing techniques. The automated test system represents an investment of about $100,000. The presently used manually operated systems represent capital investments of about $35,000. By tripling the capital investment we increase the productivity about ten times. We think this is a worthwhile trade off, particularly in applications where productivity over sustained period of time is important.

We believe that automated testing will also be important in other cases where a comprehensive and accurate technical appraisal of a cable system is prequired, e.g. when a system is being sold or when management requires a "technical audit". We believe that it is important to be able to make a meaningfull number of measurements in a conveniently small period of time. We obviously cannot test every subscriber tap in a system. Testing and technical appraisal is therefore statistical in nature. We can significantly improve the reliability of the appraisal if we increase the number of points tested. It is expensive to wait for the manual testing of a statistically significant number of test points because a substantial amount of money is tied up during this time. The speed of automated testing is therefore a very attractive feature. The added precision and accuracy is a valuable bonus.

FUTURE ADVANCES IN AUTOMATED TESTING

We look forward to additional forms of automated test systems for cable television application. Our next automated system will no doubt be a computerized automatic video baseband testing system, probably the new Tektronix ANSWER II system. This system converts video waveforms to digital form for measurement and analysis. We are working on a programmable tuner for the Tektronix demodulator that will enable fully automated tuning and analysis of cable television video channels.

Although we operate RF cable distribution systems our subscribers look at video waveforms displayed on their television receivers. The ability to examine these waveforms in detail on an automated basis will be a valuable augmentation of the automated RF capability we are presently introducing. We expect to have this automated video baseband testing system in operation about one year from now.

8568A PERFORMANCE SUMMARY

FREQUENCY

MEASUREMENT RANGE
100 Hz to 1500 MHz dc coupled and 100 kHz to 1500 MHz ac coupled.

DISPLAYED RANGE
From 100 Hz full span to 1500 MHz full span.

RESOLUTION
3 dB bandwidths of 10 Hz to 3 MHz in a 1, 3, 10 sequence.

SPECTRAL PURITY
Noise sidebands > 80 dB below peak of CW signal at frequency offsets ≥ 30 × resolution bandwidth setting, for resolution bandwidths ≤ 1 kHz.

ACCURACY

Center Frequency
± (2% of frequency span + frequency reference error × tune frequency) using error correction.

Marker
Normal: Same as center frequency accuracy.
Freq Count: Frequency reference error × displayed frequency ± 2 counts (span ≤ 100 kHz).

Frequency Reference Error (aging rate)
$< 1 \times 10^{-9}$/Day (2×10^{-7}/Yr).

AMPLITUDE

MEASUREMENT RANGE
−137 dBm to +30 dBm or equivalent in dBmV, dBμV; 32 nV to 7 V.

DISPLAYED RANGE
10,5,2,1 dB/div and linear calibration; a 10 division vertical scale.

DYNAMIC RANGE

Spurious Responses
Second harmonic distortion and third order intermodulation distortion > 70 dB below signal levels ≤ −30 dBm at the input mixer.

Average Noise Level
< −137 dBm in 10 Hz resolution bandwidth.

ACCURACY
Measurement accuracy is a function of technique. The following sources of uncertainty can be summed to determine achievable accuracy: (at constant ambient temperature, assuming the error correction function is used and avoiding unnecessary control changes between calibration and measurement):

Calibrator Uncertainty
±0.2 dB.

Frequency Response Uncertainty
± 1.0 dB.

Comparison Uncertainty
(resulting from **one** of the following techniques for comparing the unknown signal with the calibration level)

Repositioning Signal to Calibration Level:
± 1.7 dB.

Using Marker: ± 1.7 dB.

SWEEP

TIME
20 msec full span to 1500 sec full span. Zero Frequency Span, 1 μsec full sweep to 1500 sec full sweep.

INPUT

RF INPUTS
100 Hz to 1500 MHz, 50 Ω dc coupled (BNC fused); and 100 kHz to 1500 MHz, 50 Ω ac coupled (type N).

MAX INPUT LEVEL
ac: +30 dBm (1 watt) continuous power; 100 watts, 10 μsec pulse into ≥ 50 dB attenuation.
dc: 0 volts dc coupled input and ±50 volts for ac coupled input.

ATTENUATOR
70 dB range in 10 dB steps.

OUTPUT

DISPLAY
X, Y, and Z outputs for auxiliary CRT display.

RECORDER
Horizontal sweep output (X), video output (Y), and penlift/blanking output (Z) to drive an X-Y recorder.

INSTRUMENT STATE STORAGE

Up to 6 sets of user defined control settings may be saved and recalled.

REMOTE OPERATION

All analyzer control settings (with the exception of video trigger level, focus, align, intensity, frequency zero, and amplitude cal) may be programmed via the Hewlett Packard Interface Bus (HP-IB).

SYSTEM DESIGN AND OPERATION WITH "BASIC"

James B. Grabenstein

POTOMAC VALLEY TELEVISION CO., INC.

This paper will present a list of basic programs that can be used with micro computers for day to day operation of cable tv systems. The programs can be used in micro computers, now on the market. The use of "basic" is a good introduction to learning computer concepts and the digital technicality.

It is not the intention of this paper to come up with any new concepts in computer technology. I will attempt to point out how I got started and some of the standards, I think, the CATV industry needs to follow.

Over the past couple of years I have built several microcomputer systems using the IMSAI 8080 as the base for these systems. In building the IMSAI 8080 systems I have found it extremely difficult to program any practical complex programs using machine language. I find machine language programs very difficult to Debug, consequently, I had to discover a language that was conversational and contained error codes. "Basic" seemed to be the answer.

The local community college was offering a course in "Basic", so I enrolled in it. The course offered theory and terminal time and after a few hours we were working simple programs. Then applying what we had learned to our home terminals programming became a much more understandable and easier to debug.

"Basic" is a fairly simple language to understand and requires little computer theory to understand and operate. It is becoming a standard language in most colleges and high schools throughout the country. So it is not difficult to find classes full or part time in most areas of the country. For the home study enthusiast, many books are available from college book stores, radio and TV supply companies, and micro computers stores. Most of these books are geared as study guides for home study. I have found our local instructors to be as interested in getting involved in "Basic" as we were.

One of the by-products of taking the "Basic" course, I soon found a number of people in our area with interest in microcomputers. Each trying to apply micro technology to their hobby or their business. From this group a local computer club was formed. The club now meets regularly with a constant exchange of ideas and information.

One of the first things we discovered was that we each has a different system. Most of them being built up from componets of varying manufacturers. Each system having different recording or punch systems different Central Processing Unit, in addition each machine's "Basic" had a different dialect or some control code that made exchanging material direct impossible. To exchange programs we would print the program in list form, then correct it for your machine. Then re-insert it in your own system by using a header on the program as to the machine it was originated on, who wrote it, and the amount of memory used. This helped to trace any problems you may encounter. Regular debugging sessions were held at the club or at the class.

Over the past year with the introduction of the TRS-80 Level II System, it has made a package system available to more people in our industry. There are some excellent people writing programs in this format now. I feel we should try to adopt some standard so an easy exchange of programs and date can be established in a uniform format and language exceptable to the majority of our industry assoon as possible. A better method should be the use of frequency shift keying using the seriel input and output of the input/output board. Using the same board rate as your keyboard with ASCII characters. This system is being developed by Lew Strock,at this time, so we can interface my IMSAI to his TRS-80.

The TRS-80 uses "Microsoft Basic" which is used in a large number of packaged systems now on the market. These systems are well in the price range of most CATV operations and would require a very little dialogue change.

As the system I have used Microsoft Basic and Lew Strock's TRS-80 uses a Microsoft Basic. We wanted to test for any language errors.

To test this interchangeability a program that was written in "Mits Basic" into a 8080 C.P.U. was rewritten by Lew Strock, of Antietam Cable Television, for a TRS 80 Level II. The program was taped and sent to Bob Luff of the NCTA, for a test run. We had no problem with interchangeability. The program is listed on the next page.

The short programs listed below are part of the original program written in "Mits Basic". Each small program can be entered into most any "Basic" format as a subroutine or as a complete program. These programs are examples of application that can be fuctional in day to day operations of CATV systems. One thing to keep in mind when starting programing a micro computer: Keep your format simple and do not try to program over your head. Try to take one step at a time and programing will fall in place.

The listing on page 4 starting with line 600 is a program intended as training material. The intention is to show the relationship between carrier to noise of an individual piece of equipment to the signal to noise of an entire system. The formulas in this program may have value for other applications.

```
200 REM FIELD INTENSITY (UV/M) WHEN FREQ. & DB ARE KNOWN
201 REM  REF. ODB=1MV
205 INPUT"DIPOLE LEVEL IN DBMV(ODB=1MV)";D
210 INPUT"WHAT FREQ.(MEG. HZ.)";H
215 LET E1=EXP(LOG(10)*D/20)
216 LET E=1000*E1
217 LET F=.021*E*H
220 PRINT"DIPOLE DB LEVEL";D
225 PRINT"DIPOLE UV LEVEL";E
230 PRINT"UV PER METER    ";F:PRINT:GOTO 205
```

```
260 REM THIS PROGRAM WILL LIST VOLTAGE TO DB LEVELS(ODB=1MV)
265 INPUT"MICROVOLTS";E1
270 E=E1/1000
275 E2=1
280 LET D=20*LOG(E)/LOG(10)
285 PRINT D"DB OR A RATIO OF "E2":"E
290 PRINT
295 GOTO 265
```

```
300 REM NOISE FIGURE OF A CASCADE OF IDENTICAL AMPLIFIERS
315 INPUT"N/F OF OF ONE AMP.------------";F1
320 INPUT"NUMBER OF AMPS. IN CASCADE   ";N
325 LET FM=10*LOG(N)/LOG(10)+F1
330 PRINT N" AMP. NOISE FIGURE"FM" DB"
349 PRINT:GOTO 300
```

```
235 REM FIELD INTENSITY WITH (UV & FREQ. ARE KNOWN
236 PRINT
240 INPUT"UV";E
245 INPUT"MEG.HZ.";H
250 LET F=.021*E*H
255 PRINT"UV/M="F:GOTO 235
```

```
**************************************************************
*               C A T V   P R O G R A M S                    *
*                                                            *
**************************************************************

1 REM  8080  8K BASIC  MITS(MICROSOFT)
2 REM  16K OF MEMORY  (16384D) (4000H)
3 REM  POTOMAC VALLEY TELEVISION CO.
4 REM  BY JIM GRABENSTIEN
5 REM  UP-DATE: FEBRUARY 1979
6 REM  MODIFIED FOR RADIO SHACK TRS-80 LEVEL II BASIC
7 REM  ANTIETAM CABLE TELEVISION
8 REM  BY LEW STROCK
9 REM  FEBRUARY 1979

100 CLS : PRINT
"**************   C A T V   P R O G R A M S   **************"
105 PRINT
110 PRINT "1 =  FIELD INTENSITY WITH DB & FREQ KNOWN"   : PRINT
115 PRINT "2 =  FIELL INTENSITY WITH UV & FREQ KNOWN"   : PRINT
120 PRINT "3 =  MICROVOLIS TO DBMV CONVERSION (ODB=1MV)": PRINT
125 PRINT "4 =  NOISE FIGURE FOR IDENTICAL AMP CASCADE" : PRINT
130 PRINT "5 =  SIGNAL TO NOISE OF CATV SYSTEM"         : PRINT
135 PRINT : PRINT
140 INPUT "ENTER THE NUMBER FOR THE PROGRAM YOU WISH TO RUN ";I
145 ON I GOTO  200  , 300  , 400  , 500  , 600

200 REM  FIELD INTENSITY (UV/M) WHEN FREQ. & DB ARE KNOWN
205 REM  REFERENCE ODB = 1MV
210 CLS : PRINT
"*****   F I E L D   I N T E N S I T Y   P R O G R A M S   *****"
215 PRINT : PRINT
220 INPUT "ENTER DIPOLE LEVEL IN DBMV  (ODB=1MV) ";D
225 PRINT
230 INPUT "ENTER THE MEASUREMENT FREQ IN MHZ     ";H
235 PRINT : PRINT : PRINT
240 LET E1 = EXP (LOG (10) * D / 20)
245 LET E = 1000 * E1
250 LET F = .021 * E * H
255 PRINT "FOR A DIPOLE LEVEL OF "; D ;"DBMV AT"; H ;"MHZ"
260 PRINT
265 PRINT "THE CALCULATED FIELD INTENSITY IS"; F ;"UV/METER"
270 PRINT : PRINT : GOSUB 900
275 GOTO 200

300 REM  FIELD INTENSITY WHEN UV & FREQ ARE KNOWN
305 CLS : PRINT
"***** F I E L D   I N T E N S I T Y   P R O G R A M   *****"
310 PRINT : PRINT
315 INPUT "ENTER DIPOLE LEVEL IN UV          ";E
320 PRINT
325 INPUT "ENTER THE MEASUREMENT FREQ IN MHZ ";H
330 PRINT : PRINT : PRINT
335 LET F = .021 * E * H
340 PRINT "FOR A DIPOLE LEVEL OF"; E ;"UV AT"; H ;"MHZ"
345 PRINT
350 PRINT "THE CALCULATED FIELD INTENSITY IS"; F ;"UV/METER"
355 PRINT : PRINT : GOSUB 900
360 GOTO 300
```

```
400 REM THIS PROGRAM WILL CONVERT VOLTAGE LEVELS TO DBMV LEVELS
405 CLS : PRINT
"**   V O L T A G E   T O   D B M V   C O N V E R SII O N   **"
410 PRINT : PRINT
415 INPUT "ENTER LEVEL IN MICROVOLTS ";E1
420 PRINT : PRINT : PRINT
425 E = E1 / 1000
430 F2 = 1
435 LET D = 20 * LOG (E) / LOG (10)
440 PRINT E1 ;"MICROVOLTS = "; D ;"DBMV"
445 PRINT
450 PRINT " WHEN 0 DB IS REFERENCED TO 1000 MICROVOLTS"
455 PRINT
460 PRINT ABS (D) ;" DB EXPRESSES A RATIO OF "; F2 ":" E
465 PRINT : PRINT : GOSUB 900
470 GOTO 400

500 REM  NOISE FIGURE OF A CASCADE OF IDENTICAL AMPLIFIERS
505 CLS : PRINT
"**   NOISE FIGURE OF A CASCADE OF IDENTICAL AMPLIFIERS   **"
510 PRINT : PRINT
515 INPUT "ENTER THE NOISE FIGURE OF ONE AMP   ";F1
520 PRINT
525 INPUT "ENTER THE NUMBER OF AMPS IN CASCADE ";N
530 PRINT : PRINT
535 LET FM = 10 * LOG (N) / LOG (10) + F1
540 PRINT "USING AMPS WITH A NOISE FIGURE OF"; F1 ;"DB"
545 PRINT
550 PRINT"A";N;"AMP CASCADE EXHIBITS A NOISE FIGURE OF";FM;"DB"
555 PRINT : PRINT : GOSUB 900
560 GOTO 500

600 REM  SIGNAL/NOISE AND CARRIER/NOISE OF A CATV SYSTEM
605 CLS : PRINT
"*****  CARRIER/NOISE & SIGNAL/NOISE OF A CATV SYSTEM   *****"
610 PRINT : PRINT
"ASSUME THE SIGNAL/NOISE OF THE TV STATION VIDEO TO BE 49 DB"
615 PRINT
620 INPUT "ENTER THE PRE-AMP INPUT LEVEL IN DBMV ";D
625 INPUT "ENTER THE PRE-AMP NOISE FIGURE IN DB  ";N
630 GOSUB 800
635 PRINT : PRINT
ABS (CN) ;"DB C/N OR"; ABS (SN) ;"DB S/N AT THE PRE-AMP OUTPUT"
640 PRINT
645 INPUT "ENTER THE PROCESSOR INPUT LEVEL IN DBMV ";D
650 INPUT "ENTER THE PROCESSOR NOISE FIGURE IN DB  ";N
655 GOSUB 810
660 PRINT : PRINT
ABS (CN);"DB C/N OR"; ABS (SN);"DB S/N AT THE PROCESSOR OUTPUT"
665 PRINT
670 INPUT "ENTER INPUT LEVEL TO THE FIRST AMP IN CASCADE ";I
675 INPUT "ENTER THE NOISE FIGURE FOR THE LINE AMP       ";N1
680 LET CN = (-59 + N1) -I : GOSUB 820
685 LET CQ = CN
690 INPUT "ENTER THE NUMBER OF AMPS IN CASCADE           ";X
695 CLS : PRINT "AMP # ","RF C/N AMP","VIDEO  S/N" : PRINT
700 FOR M = 1 TO X
705 LET F1 = 10 * LOG (M) / LOG (10)
710 LET CN = CQ + F1
```

```
715 GOSUB 830
720 F1$ = "###" : F2$ = "##.####
725 PRINT USING F1$; M ;: PRINT " ",: PRINT USING F2$; ABS (CN);
    :PRINT " DB",: PRINT USING F2$; ABS(SN);: PRINT " DB"
730 NEXT M
735 PRINT : GOSUB 900
740 GOTO 600

800 LET SN = -49
810 LET CN = (-59 + N) - D
820 LET RS = EXP (LOG (10) * SN / 10)
830 LET RC = EXP (LOG (10) * CN / 10)
840 LET SN = 10 * (LOG (RS + RC) / LOG (10))
850 RETURN

900 C$ = " "
910 PRINT "PUSH ENTER TO CONTINUE USING THIS PROGRAM OR"
920 INPUT "ENTER AN X TO RETURN TO THE SELECTION SCREEN  ";C$
930 IF C$ = "X" GOTO 1 ELSE RETURN
940 END
```

****

These programs are an example of what can be done when industry and individuals start to exchange programs and ideas. A few words of caution. Programs should be structured so they can be followed in step by step order. Keep them simple. Check them for accuracy. Give credit to the program's originator.

One reason I feel that I can give a vote to standardizing on the TRS-80 Level II or a similar format, I know the problems I have encountered with a system that has no direct interchangeability.

If you are starting into a system, start simple and have interchangeability with someone and be prepared to spend many hours. Micro computers have unlimited possibilities but it takes time, patience, and a lot of hard work to make them productive. Your knowledge of digital technology will grow with each problem you solve.

Any program is only as good as the data entered and accuracy of the program itself. Another thing you will find is you will never be satisfied with a program and you will want something changed. I find this in my own programs or one I obtain from other sources.

I would like to thank Lew Strock for the time and effort he put into coverting the "Mit" programs into Level 11 Basic and Bob Luff in cross checking the tapes.

The program on page 6 is an example of material from industry. These programs are very handy to have at your finger tips like any other reference material. If you had to design programs of this caliber each time you needed them, your time would be spent programming and not working A good exchange of programs is needed and Ray Daly is working towards this goal.

I am in favor of such exchanges and will back any other efforts to the best of my ability. Many such high quality programs written in basic for larger systems are available. These programs are very easily adapted to micro computer systems. It is my hope we can excourage you, who have materials, to share them with the CATV industry.

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"Technical Handbook for CATV" 3 Addition March 68
Ken Simmons

"Programming with Basic"
Byron S. Gottfried

"Introduction to Computing A Basic Approach"
Richard E. Esposito

Another test that was made a program was obtained from Hughs Microwave. Thanks to Abe Sonnenschein and Norman Woods. This program was written for a Wang Computer and was formatted by Lew Strock for the TRS-80 Level II.

```
100 REM  THIS PROGRAM WILL COMPUTE DISTANCE AND AZIMUTH
110 REM  GIVEN LONGITUDE AND LATITUDE OF TWO POINTS
120 REM  FORMATTED FOR  TRS - 80   16K   LEVEL II
130 REM  LEW STROCK - ANTIETAM CABLE TELEVISION
140 REM               HAGERSTOWN, MARYLAND
150 REM  UPDATE : FORMAT AND DISPLAY 02/24/79
160 REM  ADAPTED FROM A PROGRAM IN WANG BASIC FROM USED MICROWAVE
170 REM  DIMENSION STRINGS AND DEFINE DOUBLE PRECISION
180 DIM A$ (100), B$ (100)
190 DEFDBL A-L
200 REM  CLEAR SCREEN AND GET XMTR SITE NAME AND LOCATION
210 CLS:PRINT TAB(15)"D I S T A N C E  /  A Z I M U T H":PRINT
220 INPUT "TRANSMITTER LOCATION          ";A$
230 REM  CONVERT DEGREES-MINUTES-SECONDS TO ONE NUMBER
240 INPUT "TRANSMITTER LATITUDE -  D,M,S ";D,M,S
250 L1 = D + ( M + (S/60)) / 60
260 INPUT "TRANSMITTER LONGITUDE - D,M,S ";D,M,S
270 L2 = D + ( M + (S/60)) / 60
280 REM  GET RCVR SITE NAME AND LOCATION
290 PRINT
300 INPUT "RECEIVER LOCATION          ";B$
310 INPUT "RECEIVER LATITUDE -  D,M,S ";D,M,S
320 L3 = D + ( M + (S/60)) / 60
330 INPUT "RECEIVER LONGITUDE - D,M,S ";D,M,S
340 L4 = D + ( M + (S/60)) / 60
350 REM  FIND ANGLES  A - B - C  AND CONVERT TO RADIANS
360 A = L2 - L4  :  A = A * .0174532925
370 B = 90 - L1  :  B = B * .0174532925
380 C = 90 - L3  :  C = C * .0174532925
390 REM  COMPUTE DISTANCE AND AZIMUTH USING TRIG
400 E = COS(B) * COS(C) + SIN(B) * SIN(C) * COS(A)
410 F = ATN (SQR (ABS (1-E[2)) / E)
420 G = (COS(C) - COS(F) * COS(B)) / (SIN(F) * SIN(B))
430 H = ATN (SQR (ABS (1-G[2)) / G)
440 REM  CONVERT H BACK TO DEREES
450 H = H * 57.2957795785523
460 IF H > = 0 THEN 490
470 H = H + 180
480 REM  CONVERT F BACK TO DEGREES
490 F = F * 57.2957795785523
500 REM  FIND DISTANCE BY KNOWN DISTANCE SCALE OF CO-ORD
510 I = F * 69.05
520 J = SIN(A)
530 REM  CONVERT J BACK TO DEGREES
540 J = J * 57.2957795785523
550 REM  DISPLAY RESULTS OF COMPUTATIONS
560 PRINT : PRINT A$ ;" TO "; B$ : PRINT
570 PRINT "DISTANCE = "; USING "###.##" ; I ;: PRINT "  MILES";
580 IF J > 0 THEN 600
590 H = 360 - H
600 PRINT "          ";
610 PRINT "AZIMUTH = ";USING "###.##"; H ;: PRINT "  DEGREES"
620 PRINT
630 REM  GO BACK TO GET OTHER POINTS SERVED BY XMTR
640 REM  OR START OVER WITH A NEW XMTR SITE
650 Q$ = " "  ' RESET Q$
660 INPUT"ENTER AN X TO CONTINUE USING THE SAME XMTR SITE"; Q$
670 IF Q$ = "X" THEN PRINT @ 320,; : PRINT CHR$(31) : GOTO 300
680 GOTO 200
690 END
```

THE FIGURE OF MERIT APPROACH TO SIZING LARGE DOMSATS

JERRY ARMES

SPECTRUM ANALYSIS AND FREQUENCY ENGINEERING

ABSTRACT

A classical problem for the large domestic satellite system planner is the overall mix of types of earth stations that can be utilized in the 4 and 6 GHz bands. Because of overlapping frequency bands with the common carrier terrestrial microwave plant, earth station placement can be extremely difficult. Thus, the planner is faced with major cost unknowns in deciding how many earth stations will colocate next to existing facilities and how many will need to be placed at a remote location and linked to existing facilities via terrestrial microwave and/or cable.

An attempt to analyze each site on an individual basis results in a large computer printout of each site with multiple potential great circle interference cases and beam intersections. Thus, for a large number of earth station locations, the sheer volume of data becomes overwhelming.

Spectrum Analysis and Frequency Engineering (SAFE) has defined and successfully used a Figure-of-Merit to solve this problem. This paper is an in-depth discussion of the Figure-of-Merit approach.

INTRODUCTION

The sharing of the 4 and 6 GHz common carrier frequency bands between terrestrial microwave and satellite earth station facilities dictates a degree of coordination and caution in selecting sites and installing new equipment of either type. And while the current degree of controversy exists regarding the coordination of receive-only satellite earth stations, the potential for interference of one system into the other cannot be denied. The controversy then centers only upon what legal procedural steps will be taken as part of the coordination process.

To assist potential satellite earth station or terrestrial microwave users to find and coordinate equipment sites is one of the charters of the frequency coordination firms. Their standard approach is to maintain a data base of existing and planned facilities. Upon definition of a potential site using latitude and longitude, this data base can be "culled" or scanned to identify all systems operating or planned within a coordination contour surrounding the potential new site. In each case, the degree of direct or "great circle" and "precipitation scatter" interference levels among the systems thus identified is calculated and shown on a tabular listing. By comparing these calculated interference levels to a set of interference objectives, the degree of shielding or other loss-required is identified, which will allow transmissions from each surrounding facility to allow the new installation to operate with the assurance that interference will be below acceptable levels.

In the course of this analysis, it is not uncommon to generate a computer printout fifty pages thick for each potential site.

The planner of a domestic satellite system will often represent an organization which (1) has numerous existing facilities, perhaps many hundreds or thousands, to which information is to be relayed via satellite, (2) requires the most accurate information regarding cost which can be obtained regarding satellite communication hardware to assess the economic viability of the project with respect to the particular circumstances, and (3) requires meaningful ways to "break out" those blocks of the proposed system which can be done on an incremental basis to reduce the overall program risk.

In order for the planner to assess fifty pages of printout for each proposed site, and alternate sites for those with excessive interference levels, for several hundred or several thousand sites, and produce meaningful summary information to higher management in a reasonable amount of time would be almost impossible using standard coordination procedures.

To solve the problem, Spectrum Analysis and Frequency Engineering (SAFE), a business area of Rockwell International Incorporated, developed a Figure-of-Merit (FOM) which would allow the analysis of each potential earth station site to be distilled into a single number for the initial planning stages of a domestic satellite program. Thus the planner could then be given one of four categories representing the range of the FOM.

By being able to quickly identify which of the existing properties were useable, a quantity of "rubber stamp" sites could be identified as the logical first phase of a program. Scheduling and cost analysis of these sites then follows easily. The other three categories produce similar planning guidelines.

In this paper, the Figure-of-Merit approach is discussed, and the application to the now operational Public Broadcasting System Satellite Interconnect System and the proposed National Public Radio and Holiday Inn Systems are reviewed.

THE FIGURE OF MERIT

Two basic definitions are required to build the basis for understanding of the Figure-of-Merit approach, namely (1) great circle interference, and (2) precipitation scatter interference.

Great circle interference occurs when an interference signal propagates over the surface of the earth or via direct line of sight paths into the main beam or sidelobe of the antenna of a receiving station.

Precipitation scatter interference occurs when (1) the main beams of two stations intersect, and (2) particle matter such as rain or snow in the common volume of the beam intersection causes a transmission from one to reflect into the receiving antenna of the other.

For the analysis of a given site, the geodetic coordinates (latitude and longitude) of a desired earth station site are input to the computer. A computer cull of the data base identifies those terrestrial facilities within a pre-determined "coordination contour" Interference objectives are input to the computer. Interference levels at each receiver are made by the computer and compared to the interference objectives. The difference represents a "loss-required" that will necessarily be derived from terrain features, buildings, or other shielding.

The computer calculates a loss-required between the proposed earth station site and every surrounding terrestrial facility, for each great circle case, and a precipitation scatter loss-required or margin, for each beam intersection. When one considers the nature of the precipitation scatter interference, it becomes apparent that, with the exception of waveguide loss in the receiving station, there is no way to shield against it.

From the preceding discussion then, it becomes apparent that the desirability of a proposed earth station site becomes a function of three variables predominately; (1) the number of great circle interference cases, (2) the amount of loss-required on the great circle cases, and (3) the number of precipitation scatter interference cases which have negative margins, or exceed the predetermined interference objectives.

In order to consolidate the great circle cases, the first key assumption is that azimuth is not normally a crucial factor. The horizon gain of an antenna normally varies from +5 db on the azimuth of the main lobe to -10 db at the side or back of the antenna. Thus over a 360 degree azimuth range, the earth station discrimination range is at least 15 db. However, 15 db of shielding can often be obtained by judicious earth station placement or the use of small shrubs or trees for shielding a critical azimuth.

By treating all great circle cases as differing only by the amount of loss-required, and ignoring their azimuth around the planned earth station location, a histogram can be constructed which relates great circle loss-required to frequency of occurrence. A sampling of that histogram at three percentile points then provides a representative assessment of the amount of great circle interference seen by the planned earth station location.

Subsequently, the Figure-of-Merit is defined as follows:

$$FOM = a_1 X_1 + a_2 X_2 + a_3 X_3 + b Y$$

The X values represent the great circle loss-required values at the samples taken at three percentile points on the histogram. The Y value represents the number of negative margin precipitation scatter cases, and the a and b coefficients are based on empirical data from hundreds of earth station sites coordinated by SAFE in previous years.

In order to make the FOM usable, four categories have been defined as follows:

RANGE	CATEGORY	MEANING
$FOM < 150$	OK	Site has at most one critical potential interference source which could be blocked by existing buildings or the addition of trees or shrubs.
$150 \leq FOM \leq 300$	INSPECT	Site has two or three critical potential interference sources, and levels are such that a review of terrain maps should be made to assess the amount of terrain shielding before declaring the site OK.
$300 < FOM \leq 500$	MEASURE	Site has enough potential interference that on-site Radio Frequency Interference (RFI) measurements will be required.
$FOM > 500$	MOVE	Site has unacceptable levels of interference, and another site should be selected.

Previous use of the Figure-of-Merit established it as a conservative model which correctly identified OK sites with a 95% or better confidence level. For example, on the Public Broadcasting Satellite Interconnect System, the FOM analysis on the initial 133 sites was correct on the OK sites 96.15% of the time. Two-thirds of the INSPECT sites examined were ultimately determined to be OK. Of the MEASURE sites, 80.77% were ultimately determined OK, but only 26.67% of the sites categorized as MOVE sites were finally established to be OK sites. Thus, the summary of Figure 1 provides good validation for the overall approach.

FIGURE 1

PBS PROGRAM FOM VALIDATION

CATEGORY	PREDICTIONS	NUMBER COLLOCATED (OK)	PERCENTAGES
OK	26	25	96.15
INSPECT	51	34	66.67
MEASURE	26	21	80.77
MOVE	30	8	26.67
TOTALS	133	88	66.17

Similar results were obtained for the National Public Radio Satellite System, which as of this writing, has been fully coordinated, but has not yet been constructed. These results are given in Figure 2.

FIGURE 2

NPR PROGRAM FOM VALIDATION

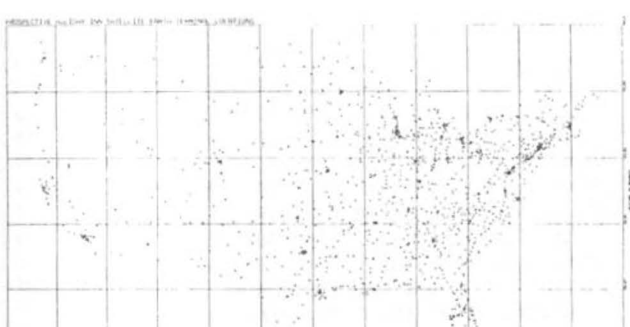
CATEGORY	PREDICTIONS	NUMBER COLLOCATED (OK)	PERCENTAGES
OK	57	55	96.49
INSPECT	60	50	83.33
MEASURE	30	17	56.67
MOVE	17	2	11.76
TOTALS	164	124	75.61

THE PROPOSED HOLIDAY INN SATELLITE SYSTEM

The most recent application of the FOM to a proposed large domestic satellite system was for that proposed by Holiday Inn for movie distribution to potentially 1533 inn locations in the U.S. Those locations are scattered over the entire U.S. as seen in Figure 3, and as such, the entire range of interference environments throughout the country will be encountered.

FIGURE 3

PROSPECTIVE HOLIDAY INN SATELLITE EARTH TERMINAL LOCATIONS



Since the proposed earth stations were to be used for video traffic, and were consequently wideband installations, SAFE counseled against attempting to make each earth station a transmit site in the 6 GHz band due to the heavy terrestrial environment depicted in Figure 4. Thus the FOM study was done to determine what proportion of the 1533 sites would work acceptably as receive-only sites in the 4 GHz band as depicted in Figure 5. The results of that study are given in the histogram of Figure 6.

FIGURE 4

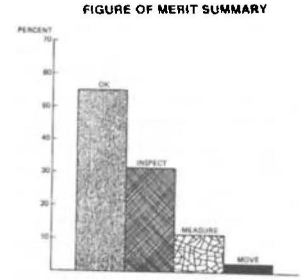
UNITED STATES ROUTE MAP — 6 GHZ

FIGURE 5

UNITED STATES ROUTE MAP — 4 GHZ

FIGURE 6

HOLIDAY INN FIGURE OF MERIT SUMMARY



CONCLUSIONS

The Figure-of-Merit approach to sizing domestic satellite systems has been validated by two large system applications and used in the planning stages of a third. As a tool for risk reduction, and "breakdown" of the planning of a large system such that logical program segments are addresed seperately, far more accurate cost and schedule information can be derived than would otherwise be possible. The OK sites can be established as a Phase I wherein the hardware will be essentially the same, and little site preparation costs related to shielding will be incurred. The INSPECT and MEASURE sites will require substantially more engineering to determine ultimate outcome,but the percentage figures of Figures I and 2 provide some general guidelines. And finally, the MOVE sites represent in general,new land acquisition or use of land other than that orginally planned. In many cases, these sites will require a terrestrial microwave link back to the original site.

ACKNOWLEDGEMENTS

The author wishes to thank Mr. Conley Saltz of Holiday Inn, Inc. and Mr. G.P. Marr, General Manager of SAFE, for a substantial degree of assistance and insight in support of this paper.

THE MEASURE AND PERCEPTIBILITY OF COMPOSITE TRIPLE BEAT

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ABSTRACT

This paper describes the result of a study done under field conditions as to the measure and perceptibility of composite triple beat. Two interesting conclusions are drawn: (1) the threshold of perceptibility under field conditions particularly with regard to Pay Television signals and their contents occurs at a ratio of 57 db carrier to composite triple beat; (2) measurements of the composite triple beat near system generated thermal noise, such as those conducted on the trunk lines, require special consideration and techniques to insure their accuracy.

THE PERCEPTIBILITY OF THE BEAT

Existing work by Arnold and others has established the threshold of the visibility of the composite triple beat to be at/or near 54 db. This can be repeated under the conditions described by the various authors. It is also widely recognized that with any channel loading above 25 the composite triple beat becomes the predominant distortion to be recognized. Pay television has brought a much heavier channel loading to many systems previously not burdened by the composite triple beat buildup that full loading would otherwise generate, and perhaps more interestingly the program content of the pay television signal (or signals) is of a type that does not carry as high an average picture level as broadcast television. Broadcast television is often thought to carry an average picture level in the 50% or higher range while the movies that make up the bulk of pay television program material are thought to have an average picture level of something near 40%.

In addition, the propensity of the subscriber to judge the quality of the pay television channel very harshly is increased because it is one for which he pays a good deal more money than the other channels carried on the system.

For these reasons it especially is important to minimize the perceptibility of the composite triple beat of these premium channels. The beat is composed, as has been recorded by the other work referenced, of many discrete carriers that when added together closely approximate a burst of random noise centered within 30 KHz of the carrier frequency. The beats manifest themselves on a television receiver screen as striations of a duration up to one or more horizontal lines occurring on a random basis. On any fairly broadband detector (approximating a television set), they can be observed to be momentary pulsations that appear above thermal noise by some 4 to 6 db (depending on the cascade depth and noise buildup). Of course this is the property which makes them visible above thermal noise on the television sets.

The traditional manner of measure in order to exclude other distortions is to observe a 30 KHz slot whose center is the carrier frequency, with heavy filtering in order to determine the approximate RMS value of the buildup, referenced to the carrier amplitude. It is in this measurement described that 54 db or greater is the necessary separation from carrier reference for the beats not to be perceptible. These conditions however, were determined with a carrier modulated to 87.5% with a video signal essentially noise free, such as a color bar generator or other test pattern. Under the condition in which the modulation depth is only 40% the apparent ratio of signal to interference to the display device is reduced by approximately 3 db. The perceptibility for these channels occurs at -57db.

Perceptibility is difficult to gauge and establish, but using the same trained observers, there has been correlation in five separate tests with five types of equipment for generation and measurement on five types of amplifier equipment that this effect can be emperically observed, and that the threshold of perceptibility for composite triple beat under conditions such as on a pay television signals of 40 to 35% modulation is 57 db. This depth modulation was chosen to approximate the level of grey scale information most observed for significant portions of the programming.

It is widely recognized that the CW tests are more harsh than the real world signal carriage conditions would bring about. It is also realized that the design to the threshold of the perceptibility arrived in this fashion leaves some headroom for operational variance, of the same order as to design for the threshold of perceptibility of synchronous cross modulation. For pay television work this design figure should be 57 db in order for the pay signals at their lower depth modulation not to be impaired by the effects of composite triple beat.

MEASUREMENT

It is quite important in many cases to measure the composite triple beat buildup on the trunk line in order that judgements may be made about equipment performance; also, judgements may be made on the basis of these measurements about the extension of the trunk line; and also trouble shooting techniques are often applied where composite triple beat is measured at various points on the trunk line. It is characteristic of present day amplifiers for the composite triple beat generated at any appreciable cascade depths to be at a level hardly discernable above thermal noise under the conditions of its measure.

It is recognized and is published in the various literature associated with measurement techniques of this nature that measurements near noise may be subject to a correction factor. It is important to note here that the thermal noise generated by the system may lie 10 to 15 db above the noise floor of the spectrum analyzer where other uncertainties do exist. There is a correction factor often applied which was generated both empirically and supported by some analytical work by a manufacturer of test instrumentation. This work assumes that composite triple beat will closely approximate a CW source. Empirical observations will show, however, that composite triple beat will closely approximate a random noise source, and will add as two power sources on a power basis. Measurements made near noise are subject to the correction factor shown in Table I and it is obtained analytically from a 10 log power addition where the resultant display is the sum of the noise floor and the distortion signal. Also given in the table are the various empirical observations that lend credence to the validity of the assumptions. The test arrangement is shown in Figure 1. The data in the table have been observed to hold for three types of spectrum analyzers in common usage in our industry.

Again, the correction is only applicable in cases where the trunk thermal noise is the limiting factor and the beat near the noise must be measured. In the feeder lines, the level of the beat is significantly above the noise and the necessary correction is negligible.

CONCLUSIONS

Threshold of perceptibility for the typical program content carried on a premium television signal should be thought of to be 57 db, and is different than the 54 db established in previous observations for test signals (of high luminous and chrominance content) modulated at 87%. Given that pay television signals are subject to closer scrutiny and more harsh judgement by the subscribers and that the current prices of a db of distribution level is thought to be at or near $50.00 per system mile for most designs today, the increase in the composite triple beat specification to 57 db for a system that is intended realistically to operate under a 35 channel loading condition should be considered and compared to the cost of service calls that may otherwise be generated.

In order to measure the composite triple beat generated by the trunk near the thermal noise generated by the trunk, an appropriate correction factor must be used for the combination of the two sources and their resultant within the instrumentation to be accounted for.

ACKNOWLEDGEMENTS

Analytical and emperical data were contributed by Joe Preschutti, of C-Cor; emperical data was also generated and contributed by R. A. Kreiger of Jerrold, and Tom Polis of Magnavox.

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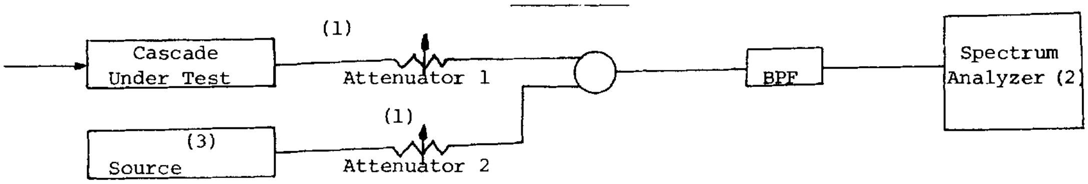
TABLE I

EXPECTED & MEASURED CORRECTION

FACTORS FOR CTB MEASUREMENTS

Spectrum Analyzer Display; db Above Thermal Noise	Correction Factor, db Expected (10 log)	Measured, CW	Measured, CTB	Measured Random Noise	Measured R. A. Kreiger
1	6.8	3.5	6	6	6
2	4.3	2.5	5	4	5
3	3.0	1.5	3	3	3.9
4	2.2	1.0	2.5	2	3
5	1.6	0.5	1	1.5	2.3
6	1.2		1	1	1.7

FIGURE 1



Procedure: Attenuator 1 was adjusted for a system noise floor ≥ 15 db above the noise floor of the spectrum analyzer (and about 60 db lower than standard signal level). The level of the source was varied from 20 db above the noise to that point at which the signal could not be discerned on the analyzer display. The difference between the calibrated attenuator and the reading of the display was recorded as the correction factor.

(1) Laboratory quality attenuator

(2) Calibrated to manufacturer's specifications. Controls were adjusted for typical CTB measurement; 30 KHZ IF with noise averaging filters in.

(3) One of the three:
1) Random noise
2) CW signal
3) CTB signal generated from a distribution amplifier, (but without components outside 30 KHZ from carrier frequency).

"WHEN ALL ELSE FAILS, DO IT YOURSELF"

GLENN CHAMBERS

AMERICAN TELEVISION AND COMMUNICATIONS CORPORATION

An update on what one company is doing to further the education of their technical employees. Covers the types of training and material used, as well as providing a look at future plans.

Last year at the NCTA Convention in New Orleans, we discussed some of the problems associated with finding qualified technical personnel. It seemed that everyone had the same problem, but no one was too sure what the answers were.

A year later, the problem still exists. It may even be a little worse, due to the massive construction boom that is now underway. However, at least a few of the operating companies feel that they are starting to move in the right direction. For this paper, I interviewed many people from several companies to get their input, and to find out what they were doing. Most of all, I wanted to find out if there really were any solutions to the technician shortage.

A.T.C., and at least three other MSO's, feel that they are finally moving in the right direction. Of course, being deeply involved in ATC's effort, I am confident that our way will work. Our theory has become the subject of this talk. "WHEN ALL ELSE FAILS, DO IT YOURSELF."

I would like to discuss some of the things that we are doing, or are planning to do very soon.

1.) Active recruiting. This primarily encompasses advertising in all the trade publications, plus asking our field personnel to pass along any information they may receive about potential employees. We are also making an effort to recruit recent graduates from technical colleges and trade schools. We are doing a small amount of hiring through personnel recruiting agencies also. So far, recruiting efforts by our field personnel have been the most successful in obtaining good people.

    One thing we do not do, and hopefully never will, is pirating employees from other companies. We have found that if you hire someone away from another company with more money or a high title, it won't be long until someone hires him away from you. We must receive an application or a resume from a prospective employee or we will not even interview him. We also look very hard at his reasons for leaving his last company, how long he has worked for each company in the past and we ask him directly why he feels he would like to work for ATC.

2.) Higher wages, I think that this one area that has needed revision for a long time. I won't go into details, but I can safely say that technical salaries have increased by a significant amount. It's a seller's market right now and we are the buyers. Our top people today are getting salaries that were unheard of just a very few years ago. But, if you don't pay decent salaries, a good technician can go a few miles down the road and find another job, usually at a better salary.

3.) Benefits. Neither ATC, nor any other company that I've contacted, have significantly changed their basic employee benefits in the last year. In most of the companies, benefits offered are the same package as all other companies offer. We don't feel that benefits play an important part as long as you have the basic health, vacation, sick days, etc.

4.) Education. This is an area that has been and still is playing a major part in our present future plans. We have done research into education for the last three years and have finally come up with a package that we feel will take care of 90% of our needs for years to come. I'd like to give you a little background on our previous educational efforts prior to getting into our present operation.

ATC has been an advocate of education and training for a number of years. An educational assistance policy was established to help pay for the costs. The policy was: reimbursement of 50% of the costs of any job-related course within 6 months after course completion and the final 50% after another 6 months. The time delay was intended to induce employees to stay with the company for at least one year after completing a course. If they didn't stay, they did not get full reimbursement. Needless to say, some of them stayed and some didn't. About the same percentage stayed whether they had schooling or not. The delayed reimbursement had the undesired effect of diminishing the numbers of people who took expensive courses. They couldn't afford to pay all the costs and then not get their money back for a year or two. This policy was revised and updated within the last year to our present policy.

Our present policy is: You select the job-related course and we buy it. 50% of the cost will be divided by the number of pay periods in one year. Let me give you an example: A course is bought which costs us $800.00. We pay the $800.00 and then take 50% of that amount ($400.00) and divide it by the number of pay periods per year, usually 26, which gives us $15.38. Then, $15.38 is deducted from each of the employee's pay checks until he either completes the course (with a passing grade) or until $400.00 is paid off. When the employee passes the course, deductions stop immediately. All money paid in by the employee is then refunded to him after six months. Since this policy has been in effect, the numbers of employees enrolled in courses has increased by almost 50%.

Since we still didn't feel that this was the total answer, we continued looking into other ways to improve the overall education of our employees.

The next step taken was the establishment of an installer school in one of our Florida systems. Why Florida? We had facilities available, with minor ($18,000) expenditures for material, and the Regional Engineer was an excellent teacher. We wrote all our own material, did all the drawings, made slides, etc., etc.,

The first class, starting March 26, 1979, consisted of 12 recently hired people and 14 installation supervisors. None of the new hires had any climbing or cable experience. The supervisors were included so that they would be aware of what we were teaching and how installs were to be done. I have a quantity of copies of the outlines of this course with me. If you are interested, I'll give you a copy when are through here.

This first series of classes consisted of two weeks per class, with from 16 to 20 employees in each class. When the employees left class and returned to their systems, they were fully qualified installers. Even those who had never climbed a pole or seen a cable drop could go out and make installs with the rest of the crews. Production was not quite up to that of the experienced people, about 75-80%, but the work they do is as good (or better in many cases) than that of the people who had just been trained "on the job."

We feel that this training program is an unqualified success. It is expensive, but we feel that it is money well spent. One reason for the expense is that we fly our people into Florida, pay their room and board and salary. If you exclude these costs, you are only taking about a cost of $180. to $200. per student/per class. It would cost you that much to recruit an experienced installer, and his salary would be quite a bit higher than we pay our trainees to start.

We still don't feel that this is all we want to do in education. We have now created a Department of Technical Training within ATC with a full time manager, instructors and clerical staff. Some of the things we are doing, or plan to do in the near future are as follows:

a. <u>Create specialized classes</u> so that each one of our technical people can attend at least two weeks of classes per year. The techs will be able to choose the topics which are of greatest interest to them. Some topics which we are now looking into are:

   1. Repair, alignment and maintenance of headend equipment.
   2. Microwave theory and practise.
   3. System Design.
   4. Alphanumeric theory, repair and maintenance.
   5. Video waveforms. Theory and practical application.
   6. Data transmission via cable systems.

   And many more.

b. <u>Prepare training guides</u> for use by our field personnel for in-system training.

c. <u>Prepare training taps</u> in basic electronics for use by our field personnel.

d. <u>Compile a book</u> on CATV Engineering.

e. <u>Write correspondence courses</u> for in-house home study. These will be issued at no cost to qualified employees who request them. We presently plan six courses, ranging from basic CATV theory through advanced CATV engineering.

f. <u>Continue the field seminars</u>. We presently conduct one 3 day seminar per month/per region. Since we have 11 regions, this allows us to go to the field and talk to the technicians in each region once each year. We also have all our regional and large system engineers come to Denver once each year for a high level engineering seminar.

f. Train Construction Linemen for our own construction crews.

This probably sounds like a very ambitious and costly undertaking. You are right - it definitely is, on both counts. However, ATC management is not noted for going off on wild-eyed schemes unless they are sure that the schemes will work and will pay off. We are sure on this.

If for some reason it should not work out after all the time and money we've put into it, at least we had guts enough to try and we care enough about our employees to want to help them. We tried to do it ourselves.

One last thing - if it doesn't work out, I'd like to have all your names and addresses so I can send out my resume quickly. I'm sure I'll need another job in a hurry.

Thank you.

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