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NCTA
Technical
Papers

1985 NCTA ENGINEERING COMMITTEE SUBCOMMITTEE ANNUAL REPORTS

Robert A. Luff - 1984 & 1985 NCTA Engineering Committee Chairman

Wendell H. Bailey, Jr. - NCTA Staff Liaison

INTRODUCTION

The National Cable Television Association (NCTA) has, since 1952, represented the diverse and growing cable industry before Congress and Federal agencies, in courts of law and before state regulatory agencies. As the principal trade association of the U.S. cable television industry, its members comprise cable television system operators, equipment manufacturers, program suppliers and several ancillary service providers.

Members are provided with forums (notably committees and this annual convention/exposition) where they may exchange information on developments in the industry and maintain liaison with other industries, societies and groups. The NCTA Engineering Committee is one such forum. Two-day, bi-monthly meetings held mainly at NCTA's Washington, DC headquarters, attract 50-60 top level member and non-member cable engineers from all over the country. Subcommittee chairmen reports form an important segment of each agenda.

STAFF AND SUBCOMMITTEE FUNCTIONS

To the extent that it is able to identify issues of common concern to members, NCTA strives to propose or recommend ways to address these issues. The NCTA Engineering Committee, its subcommittees and staff liaison department -- Science & Technology -- play a vital role in this continuing process. When an area of concern has been pinpointed, the Engineering Committee will most frequently turn to or create a subcommittee to address the concern. Following the compilation and analysis of a combination of original testing/research, literature reviews and survey results (every effort is made to solicit technical input from all affected interests) subcommittees report their findings to the Engineering Committee. The Committee then reviews and approves final documents and/or recommendations before NCTA acts on them -- in some cases, publishing and distributing a printed product -- though, as you will read in the following ten annual reports, often a subcommittee fills an educating, liaison or monitoring function for the Committee and no published documents result.

CHARTER

The policies of the National Cable Television Association are determined by the Board of Directors. To assist in policy formulation in technical areas, the Board establishes an Engineering Committee. The duties of the Engineering Committee are:

1) To respond on a timely basis to Board requests for advice and recommendations on technical matters.

2) To forward to the Board advice and recommendations on technical matters which the Committee perceives as having an effect on the policies of the Association.

3) To advise the Board of technical developments and innovations which the Committee perceives as having an effect on the policies of the Association.

4) To advise the Board of technical developments and innovations which the Committee perceives as having an effect on the future courses of the cable business.

5) To assist the technical staff of the Association as requested.

6) To represent NCTA by establishing liaison with international and national technical groups.

The activities of the Committee shall include, but not be limited to:

1) Regular review of FCC dockets, Notices of Inquiries, Notices of Proposed Rulemaking, etc., having impact upon the technical operation or construction of cable television systems.

2) Liaison with appropriate outside technical organizations, associations and professional societies.

3) Liaison with international organizations, associations and professional societies whose work may have an impact on the industry.

Membership on the Committee shall be open to all technically oriented employees of members of the National Cable Television Association who are interested in the work of the Committee. The Chairman of the Board of NCTA appoints the Chairman of the NCTA Engineering Committee. Individual voting members are then appointed by the Chairman of the Board of NCTA after consultation with the Chairman of the Engineering Committee.

Notice of meetings shall be sent to all members of the Committee and also sent to each member of the Association for forwarding to technically oriented employees. Attendance is open to all members of the cable industry's engineering community who are NCTA members.

ACKNOWLEDGEMENTS

Participation in subcommittee work and Engineering Committee meetings are some of the cable engineering community's most challenging but rewarding endeavors, requiring unusual professional dedication and acumen. NCTA's Science & Technology department joins Engineering Committee chairman Robert A. Luff in applauding subcommittee chairmen and members for unstinting and outstanding service to the cable industry.

-1986 NCTA Technical Papers editor, K. Rutkowski-

For further information about the NCTA or Engineering Committee, call (202)775-3637 or write to the Science & Technology department at NCTA, Washington, DC.

Annual Reports

1. Joint ARRL/NCTA Signal Leakage Committee
2. Standards For Good Engineering Practices Subcommittee
3. Consumer Interconnect Subcommittee
4. Signal Leakage Subcommittee
5. Signaling & Control Subcommittee
6. Networks and Architecture Subcommittee
7. Satellite Transmission Standards Subcommittee
8. Multichannel Television Sound Subcommitee
9. Digital Television Sets Subcommittee
10. Joint EIA/NCTA Engineering Committee

JOINT ARRL/NCTA SIGNAL LEAKAGE COMMITTEE

Robert V.C. Dickinson, Chairman

CHARTER

1. Develop low cost measurement techniques for cable leakage. Publicize these techniques in both amateur and cable circles.
2. Quantify problem under various field conditions.
3. Develop cooperative techniques and demonstrate effective procedures through working with a test cable system. Publicize these results and foster a cooperative spirit in continuing leakage correction and maintenance efforts.
4. Assist, if requested, to resolve unusual cable leakage problems.
5. Membership shall consist of Chairman, Secretary and four members from each group.

1985 ACCOMPLISHMENTS

To date, two meter calibration equipment has been developed and given limited publication in the ham radio magizine QST [per charter item #1]. Charter items 2 and 3 were addressed in tests conducted in 1984 though more exposure needs to be given to these results. Individual committee members regularly assist in special leakage problems.

Overall, the activities of the Committee in 1985 were somewhat limited. The majority of the activity consisted of individual consulting on technical cable leakage matters, plus some field testing. The field testing was aimed at course quantification of cable system vulnerability to amateur radio ingress below 30 MHz. The testing which has been done was a good start, however, several follow-ups on test exercises will be required before any publishable data is available. Members have also worked with the ARRL in editing certain ARRL publications and have assisted in handling some for the amateur complaints within the cable industry.

1986 PLANS

The program for the coming year will consist of further high frequency testing and publication of related matters to both amateur and CATV communities.

The meetings and activities of this committee are open to parties with constructive interests in this area.

STANDARDS FOR GOOD ENGINEERING PRACTICES

Michael F. Jeffers, Chairman

CHARTER

To determine the best method (or methods) for measuring parameters that can ascertain the proper operation of a cable system and to establish performance criteria for good engineering practice. Further, to publish this information in the NCTA Recommended Practices Manual. Formed: June, 1976

1985 ACCOMPLISHMENTS

Practices submitted for incorporation into the NCTA manual during 1985.

1) Graphic Symbols

2) Carrier-to-noise - CATV Systems.

3) Carrier-to-noise - (CATV) vs. Video Signal-to-Noise

4) Cross Modulation - CATV System

1986 PLANS

A Subcommittee meeting was held in November, 1985, to commence practices for coaxial cable. Four practices will be added to the NCTA Recommended Practices in 1986.

SIGNAL LEAKAGE SUBCOMMITTEE

Frank Bias, Chairman

CHARTER

Perform the following regarding signal leakage from cable TV systems: 1) Study the engineering parameters. 2) Recommend policies to the NCTA Engineering Committee. 3) Recommend construction and operation practices. 4) Liaison with ARRL Subcommittee. Formed April, 1976.

DOCUMENTS PRODUCED

Assisted in preparation of NCTA's opposition to ARINC Petition for Reconsideration and Reply to ARINC opposition to NCTA Petition for Reconsideration in Docket 21006.

Report of working group on sources of cable system leakage submitted and accepted.

Assisted in preparation of NCTA comments in FCC Docket 85-301 Cable Terminal Devices.

Assisted in preparation of NCTA comments in Docket 85-38 Cable Deregulation.

WORK PLANNED

Participation in signal leakage portion of upcoming FCC action separated from Docket 85-38 Cable Deregulation.

CONSUMER INTERCONNECT SUBCOMMITTEE

David Large, Chairman

CHARTER

The Consumer Interconnect Subcommittee is a new addition to the NCTA this year. It was formed to study and recommend short-term solutions to the problems caused by connecting increasingly complex customer video entertainment equipment to cable systems. Its function is separate from the joint NCTA/EIA engineering committee and the various EIA committees which are all working in various ways on longer-term solutions in that the latter are dependent on changes in new equipment designs while this committee is concentrating on accommodating the existing base of installed equipment.

MEMBERSHIP

The official membership of the subcommittee includes representatives from 10 MSO's and 7 equipment manufacturers plus program suppliers and industry consultants. Meetings are held irregularly as required, but most work has been done independently by members with telephone consultations as required.

HISTORY

The consensus of the group was that we should narrow our initial concerns to issues raised by connection of descramblers, VCR's and one or more television sets (which may have extended range tuning). To that end, information was gathered from over 20 MSO's on current practices with their own subscribers. Commercially available integrated switching boxes were also evaluated and ideas solicited for new approaches to the problem.

At the October, 1985 meeting, an outline for a formal report was approved. This report will contain a tutorial on interconnection issues, an indexed list of the most useful configurations using splitters and A/B switches, a model specification for an integrated configuration and discussion of alternate approaches. Appendices will cover the work of other industry groups and discuss the shielding/ingress/egress issue. As of December, 1985, this report had not yet been issued.

Future directions of the committee may include baseband audio and video interconnections, stereo television (both BTSC and out-of-band systems) and/or off-premise equipment.

SIGNALING & CONTROL

Scott Tipton, Chairman

CHARTER

To evaluate current and recommend future design goals and implementation procedures for signaling and control of various devices in cable systems via satellite. Formed: May, 1982

ACCOMPLISHMENTS

Prepared a six-page report outlining present industry needs and future requirements for signaling and control of commercial insertion devices titled: "Tone Recommendations". Report was based in part on responses to an industry survey distributed in 4th quarter, 1982. Since its issuance in March, 1984 the Tone Recommendations (2nd rev.) have been widely adopted.

1986 PLANS

Though this subcommittee is currently a group in search of another problem to solve, the NCTA Engineering Committee has asked that the chairman and members (whose company affiliations comprise a balance of MSO and programmers) sustain an "industry education and monitoring" function.

SATELLITE TRANSMISSION STANDARDS

Howard L. Weinberger, Chairman

CHARTER

To follow developments and issues related to satellite common carriers, FCC policy, or up/down link transmission state-of-the-art, and to report on these areas to the full NCTA Engineering Committee. To assist the NCTA staff and the Engineering Committee in developing responses and/or activities to deal with developments in the above mentioned areas. [subcommittee first organized in 1980]

ACTIVITIES IN 1985

The subcommittee was identified as the focal point for reporting interference problems related to reduced spacing between satellites serving the cable television industry. No significant problems have been reported.

ACTIVITIES FOR 1986

To monitor proposals for the FCC to require tagging TV uplink transmissions with an ID code in order to facilitate rapid resolution of accidental interference to other uplinks.

NETWORKS AND ARCHITECTURE

Geoffrey W. Gates, Chairman

CHARTER

This subcommittee, formed in May of 1982, is charged with studying all aspects of data transmission on cable television based media. Technologies and services which are likely to impact the cable television industry will be evaluated and the projected nature of the impact will be reported to the NCTA Engineering Committee along with recommendations for action. The subcommittee is divided into three working groups:

Cable Media, chairman: Archer Taylor
Issues: Spectral usage, gaussian noise, ingress, cross-coupling between upstream and downstream, delay, effects of signal processing, frequency allocation and network topology.

Logical Protocols, chairman: H.W. Katz
Issues: Performance of existing protocols, support (VLSI) for protocols, survey of currently used protocols.

Data Communications Services, chairman: Lawrence Lockwood
Issues: Monitor and report on regulatory actions potentially.

DOCUMENTS PRODUCED

1. Characterization of Cable TV Networks as the Transmission Media for Data -- Working Group [Archer Taylor, chair] Cable Media
2. "Existing and Evolving New Data Communications Services" -- Working Group [Lawrence Lockwood, chair] Data Communications Services

CURRENT STATUS

In May, 1985 the chairman recommended that the subcommittee on networks and architecture be dissolved upon acceptance of its final report. The Engineering Committee voted to maintain the subcommittee and its working groups as a standing subcommittee, to work toward increased member participation/support, and charged IEEE liaison, Lawrence Lockwood, with heightening interface between the Engineering Committee and one or more of the IEEE 802 standards groups.

MULTICHANNEL TELEVISION SOUND (ad hoc)

Alex Best, Chairman

CHARTER

To investigate the technical implications of the carriage of BTSC (Broadcast Television Systems Committee) multichannel sound over cable systems. Formed: August, 1982.

DOCUMENTS PRODUCED

1) Multichannel Television Sound Report -- National Cable Television Association

2) Multichannel Television Sound NCTA/EAC Subcommittee Test Plan -- Submitted to Wendell Bailey by Alex Best on behalf of the NCTA multichannel sound subcommitee.

3) Multichannel Television Sound -- Technical Implications for the Cable Television Industry -- A report submitted to Tom Keller (Chairman of the EIA BTSC Subcommittee) from Alex Best on behalf of the NCTA multichannel sound subcommittee.

4) Multichannel Television Sound -- A letter from Alex Best to Tom Keller outlining a test plan to be conducted by the EIA BTSC Subcommittee on behalf of the NCTA.

ACCOMPLISHMENTS IN 1985

The subcommittee is presently acting in a monitoring, educating, and data gathering mode. The education takes the form of presentations at trade shows and SCTE functions. The monitoring and data gathering takes the form of soliciting inputs from cable operators who are carrying BTSC sound on their systems.

PLANS FOR 1986

In 1986 the subcomittee will continue in its present mode of operation.

DIGITAL TELEVISION SETS (ad hoc)

Nicholas Worth, Chairman

CHARTER

This group's charter was to investigate digital television technology to determine whether or not new TVs employing ITT chip sets (or their equivalent) can easily defeat sync suppressed scrambled signals. And, based upon findings, to report to the full Engineering Committee, make recommendations for preventive measures and to follow through on said recommendations. Formed: August, 1984. Disbanded May, 1985.

ACCOMPLISHMENTS

In the fall of 1984 the digital TV set subcommittee completed extensive tests demonstrating that a television set employing the ITT Digit 2000 chip set can, if externally manipulated, defeat sync suppression scrambling. A report on the group's findings was presented to the Engineering Committee in November, 1984. The Committee then empowered the subcommittee to work with NCTA staff and draft a letter to television set manufacturers pointing out the concerns of the cable industry and requesting that the manufacturers not allow easy access to the data bus for the purpose of forcing the chip set into the countdown mode.

It appears that the cable industry's concerns have been taken into account by set manufacturers -- the Engineering Committee disbanded this ad hoc subcommittee in May, 1985 commending the chairman and his members for a job well done and a charter fulfilled in a timely fashion. It was suggested that the joint EIA/NCTA committee take on the monitoring/tracking function that the digital TV set subcommittee would have maintained had it remained a standing subcommittee.

JOINT EIA/NCTA ENGINEERING COMMITTEE

Robert M. Rast, Chairman
Walter S. Ciciora, Vice-Chairman

CHARTER

To establish and maintain dialogue between the cable and consumer electronics industries for the purpose of studying and resolving engineering matters of common interest. Date formed: 1982

1985 ACCOMPLISHMENTS

RF Cable Interface

The Committee's RF Cable Interface Working Group, chaired by Walt Ciciora, finalized a RF Cable Interface Interim Standard. This technical standard applies to the RF interface between a CATV cable and a subscriber's device which tunes television channels, such as a television receiver, VCR or cable converter. This standard, in combination with a previously approved channelization standard, and a decoder interface standard, discussed below, are intended to foster compatibility between cable systems and subscriber devices connected to the cable. The RF Cable Interface Interim Standard was endorsed by the NCTA Engineering Committee and is being submitted to members of the EIA R-4 Committee for approval by mail ballot. Upon approval, it will become an EIA interim standard.

DECODER INTERFACE

The last of the three standards developed to foster compatibility between cable systems and consumer electronics devices is the Decoder Interface Standard. This standard was finalized during 1985 by the Decoder Interface Working Group of the EIA R-4 Committee. While it was not directly an activity of the Joint Committee, members of the Joint Committee attended meetings and contributed to the standard. In addition, ATC hosted three field tests, in Denver, during which consumer electronics and cable hardware manufacturers jointly tested products incorporating the new interface. The Decoder Interface Interim Standard is being submitted to members of the EIA R-4 Committee for approval by mail ballot. Upon approval, it will become an EIA interim standard.

1986 PLANS

CABLE COMPATIBILITY STANDARDS SUPPORT

Although the work is essentially completed, the Committee will provide whatever support will be required for the three cable compatibility standards discussed above.

NEW ACTIVITY

Through the RF Cable Interface Working Group, the Committee has begun to address what new activity should be undertaken. The leading candidate is an investigation of scrambling and addressability approaches, practices, and needs to determine whether there is an opportunity and a need for a common definition of parameters, and possibly, standards.

RF CABLE INTERFACE AND DECODER INTERFACE WORKING GROUPS

Walter S. Ciciora, Ph.D.
Vice President, Research and Development

AMERICAN TELEVISION & COMMUNICATIONS CORPORATION

INTRODUCTION

Standards committee progress is often painfully slow. To a newcomer, especially someone accustomed to the "fast lane," this activity can be quite frustrating. There are several points to be made about this. Firstly, if cable interface and decoder interface standards were easy to achieve, they'd have been agreed to a long time ago. There's been pressure for an extended period of time. Secondly, the issues being settled are delicate points involving trade-offs which impact the economics and performance of two industries. These two industries have a history short on cooperation and long on confrontation. Fortunately, the trend toward cooperation is on the up swing.

At first blush, it would seem difficult to find two industries with more reason to cooperate than the Cable Television Industry and the Consumer Electronics Industry. Better pictures should enhance satisfaction in cable service and better choice should increase the desire for quality images. Most of the difficulties to date have been due to a lack of information and misunderstanding. Open, honest, and frank contacts should be helpful to all.

STRUCTURE

In 1982, the National Cable Television Association, NCTA, and the Electronic Industries Association, EIA, formed a Joint Engineering Committee to discuss technical issues which impact both industries. The first order of business of that committee was to create a channelization standard for frequency assignment. After considerable debate, the committee recommended the plan which became an EIA Interim Standard for one year. It has recently emerged from this probationary phase to become an official recommended standard.

It is important to note that these standards are voluntary standards. Neither the NCTA nor the EIA have enforcement powers. Adherence to the standard depends on the good faith of the companies involved.

After the channelization standard, two Working Groups were formed to consider an RF cable interface standard and a decoder interface standard. Shortly after formation of the Decoder Interface Working Group, it was discovered that the EIA R-4 Group had its own decoder interface group. Seeing little point in duplication of effort, the Joint Committee decoder working group disbanded.

ATTITUDES

An important reason for the successes of the Joint Committee has been a change of attitude on the part of the participants. In the past, cable/consumer electronics relations were marked with finger pointing and name calling. Very important technical trade-offs were the focus of arguments which had significant economic impact. This behavior has been replaced with a realization of the importance of customer satisfaction. The customer/subscriber must be satisfied if the two industries are to prosper. It is pointless to try to shift blame. The customer/subscriber demands satisfaction from both industries.

A significant step in the right direction has been the relaxation of what has been called the "70dB syndrome." In the past, the cable industry has tended to demand that any potentially harmful phenomenon be suppressed by 70dB. The consumer electronics industry has become offended by this approach since this degree of suppression is difficult to measure for most parameters and impossible to achieve in practice. The result has been near zero progress.

The "70dB syndrome" has been replaced with a much more reasoned discussion of actual problems. A phased approach has been recommended which sets achievable targets, timed to cover frequencies ranges as they are implemented in the cable practice over time. When a cable representative believes there is a need for a specification which the manufacturers feel can't be presently achieved, a tutorial is included. This motivates the manufacturers to strive for solution in future designs.

The defensive guards have been lowered and technical people are listening to one another in open dialog. People are trying to understand each others problems and accommodate.

Occasionally, a new member joins the committee and makes moves in the old ways. The committee brings the newcomer in line and progress resumes.

THE RF CABLE INTERFACE WORKING GROUP

The RF Cable Interface Working Group's major concern is the Cable Compatible Consumer Product, such as the Cable Ready TV. The committee very quickly got over the issues of connector type, impedance, and signal levels. A more serious problem has been Direct Pick Up, DPU, of broadcast signals.

The committee has taken voluntarily committed receivers and measured them in a T.E.M. (Transverse ElectroMagnetic) cell. The tests were funded by the EIA, and each participating manufacturer received data on his products. A non branded table of data was supplied for committee use. Sets ranged in performance from satisfactory behavior to sets with considerably lower levels of tolerance. Manufacturers have been carefully considering the art of radiation immunity as it applies to their products. Progress has been made.

The committee has agreed upon an Interim RF Cable Interface Standard and has gained the approval and endorsement of its parent groups.

The most significant aspect of this new standard is a ten times increase in the direct pick up specification. Under this new standard, a complying product must not show noticeable degradation of performance in the presence of broadcast electromagnetic fields having a strength of one volt per meter. The previous specification came from the Canadian standard and was based on one tenth of a volt per meter. It is expected that the new standard will cover 80% to 90% of all cable DPU problems. The remainder will require a converter to completely solve the problem.

It is important to realize that the TV receiver manufacturers have taken on a significantly greater burden with this new standard. This level of performance will be difficult to achieve. However, the customer/subscriber will benefit. This achievement demonstrates that two industries can work together to resolve difficult issues when a cooperative approach is employed.

Cable converter product has also been measured in T.E.M. cells. The goal was to understand techniques for implementing the converter's seemingly better performance.

A reoccurring problem in this committee work is the separation of performance standards from interference standards. It is felt that the regulation of performance is best left to the market place. However, the control of interference is a bona fide standards matter. Four kinds of interference have been considered in order of increasing severity: 1) Interference with the product's own performance 2) Interference with other products in the same home 3) Interference with other subscribers' reception. 4) Interference with other users of the electromagnetic spectrum, such as aircraft navigation and communications radio.

THE LONG TERM FUTURE

The logical conclusion for the trends in CATV home terminals is for subscriber ownership. This is the best outcome for nearly all concerned. The subscriber has his favorite hardware relationship, ownership. Unlike his European cousin, the US TV receiver user has historically preferred ownership to rental. The same should apply to the decoder hardware. This will especially be the case if he can own the tuner, remote control, and other convenience features as part of the bargain. These later goals are achieved by having the descrambler come after the TV receiver's tuner. There are two ways of accomplishing this. One way has a "decoder interface plug" on the back of the TV receiver (or VCR, etc.) into which the subscriber owned (or leased) descrambler fits. The second method is to build the decoder directly into the receiver by the receiver manufacturer. The latter will happen if there is a de facto or actual decoder standard which would permit free movement from cable system to cable system. If this is not achieved for what ever reason, then plug-in, re-sell, or swap devices will be required.

The principal entity which is disturbed by this approach is the manufacturer of home terminals who doesn't also make TV receivers. He sees more than half of his "value added" eliminated. But from the bigger picture, the waste and inefficiency of having a tuner, remote control circuits, and related components in the home terminal, only to have them duplicated in the TV receiver, is undesirable.

From the cable operators' point of view, the program protection method must insure that subscribers cannot defeat the system and receive the programming for free. Another interested party in all this is the programming producers. If they believe their product can be stolen, they will not make it available to the cable operator. The cable operator realizes that the would-be pirate has nearly unlimited time and resources at his disposal. The system which meets this test will be robust indeed. Once this assurance is obtained, the cable operator will gladly give up the capital requirements caused by the need to supply the descramblers. The money would be better invested in more programming, service-enhancing facilities, or home terminals that provide new services to subscribers.

THE DECODER INTERFACE WORKING GROUP

The Decoder Interface Working Group is not a Joint Committee effort, rather it is entirely an EIA activity. In spite of this, there has been significant friendly dialog between the two industries. Cable participation in this committee work has been welcomed. Specifically, there have been cable industry contributions to the design and testing of the interface plug.

The Interface Plug is also called the Cenelec 20 pin plug. Even with twenty pins, the committee wished it had more! Red, Green, and Blue, RGB, as well as composite video in and out are provided. A data line pair to communicate logical instructions such as EIA Homebus signals, has been provided. At some day in the future, it will be possible to connect consumer electronics products to a master home system. Fast blank for text insertion and decoder restored sync input pins are provided. Devices with the interface plug are intended to be "daisy chained." That is, devices may be designed in such a matter as to be connected in series, allowing interaction between devices and an extension of product into an easy to use, consumer friendly system.

The most serious and controversial issue regarding the interface plus is automatic gain control, AGC, design philosophy. AGC has two modes of operation with strongly conflicting demands, acquisition and stable operation. The circuit time constants must be different for these two modes. Additionally, the AGC time constants of the cable converter and television receiver must be significantly different so one is dominated by the other. If the two time constants are close together in value, oscillations may result. The problem is that some receiver manufacturers are using long time constants while others have decided upon short time constants. An important difficulty to appreciate is the fact that in scrambled mode, most systems suppress horizontal sync pulses. For decades, television AGC design philosophy has depended on finding and accurately measuring sync pulse parameters. The two processes are in fundamental conflict. Without sync pulses, there is a tendency for the amplifiers to increase gain and saturate. This crushes the signal and insures that sync pulses will never be found. This "lock-out" condition is a disaster which must be avoided. It is most complicated in systems which suppress sync pulses in the vertical interval as well. This phenomenon is extremely non-linear and not well understood. Some engineers insist that there is no theoretical basis for these systems to ever work! They claim that each time the system achieves synchronization and decoding, a fortunate electrical accident has occurred!

One serious complication is the fact that AGC expertise in television receivers is a scarce resource. There are probably less than twenty experts in the entire world. The subject is very complex with almost no published technical literature. Engineers become experts in this field through years of apprenticeship to an existing expert. A second complication is that competitive performance between manufacturers' products is largely determined by AGC characteristics. To someone who appreciates this, the committee interactions take on a whole new dimension. There is the careful guarding of secrets, the pained release of just enough information to make the interface plug system work, but the anxiety that too much may have been revealed to a competitor.

The Decoder Interface Working Group has had three field tests in ATC's cable systems in Denver, Colorado. Several TV receiver manufacturers and several decoder manufacturers participated with varying, but basically very good, results. The level of success exceeded expectations and re-energized the committee. At least one receiver manufacturer's engineers formed a strong alliance with a decoder manufacturer's engineers. Extensive cooperation and mutual sharing of information has resulted in a raising of the potential for success of these two companies. At least one other manufacturer took a very unfriendly, parochial approach in the first test which offended the other participants. This has caused embarrassment to others at that company who have worked long and hard at trying to establish a record of cooperation and leadership. By the second test, this was corrected.

The best indication of the success of the field tests has been the lively interchange that took place afterwards, resulting in significant improvements in the proposed standard. The most interesting improvement at the time of this writing is the proposal of an AGC time constant control pin which would yield control of the time constant to the decoder.

Current tests have concentrated on base-band scrambling schemes because the interface plug connections do not include RF signals.

Committee agreement on the interim standard was achieved by year end. The parent group approval process has begun.

First availability to TV receivers incorporating the interface plug will likely be in late 1986.

THE COMMITTEE PROCESS

The committee has a life cycle of its own. At first there is a small group of attendees trying to make it happen. Slowly the group expands until so many attend that it's difficult to get anything done. After several months, those low on patience cease to attend. Decision-making picks up. Then some dramatic event such as a field trial takes place. Once again, attendance soars. A new danger to progress takes place. New members attend for the first time. They start questioning the fundamental philosophy. Old ground is revisited. The skillful chairman must maintain progress, yet not turn off the new attendees. The new attendees will have their say in the final standards approval process. They must not be alienated. As the committee reaches the end of its work, two forces come to conflict. Those who have put in years of work want to bring it to a close. Others who have been alerted to the committees work by the expected issue of a new standard become alarmed. They see all kinds of threats to their interests and, of course, better ways to do the job, usually using advanced technology which wasn't available when the committee started its work. The committee chairman must manage these forces or total grid lock will result.

Another practical difficulty with committee work is the fact that the most likely contributors are industry experts and industry decision-makers. By definition, these individuals are very busy and in demand by their company's engineering departments and by other committees. Getting the right people involved is critical to success. Occasionally, a company's management's view of committee work is too parochial. Important contributors are denied permission to attend, or are not supported in this activity.

An important element of the committee process, is the mutual education of the two participating industries. Committee work is an excellent means of communication between experts in the cable and the consumer electronics industries. Well before an agreement on standards is reached, the TV receiver design experts are applying what they have learned from the committee work and are anticipating the new standard. This process makes timely introduction of product, based on the new standard, possible.

While it will be years before a significant penetration of product built around these standards takes place, those customers with an urgent need or desire will be able to purchase products in the second half of 1986. Thus, a timely impact will be made even though extensive use of the standard will take many years.

Thanks go to the EIA and the NCTA for their leadership in these issues. Special thanks to the EIA for sponsoring the meetings and to Tom Mock, of the EIA, in particular. The task would have been much more difficult, if not impossible, without his time and energy. And, of course, thanks to the committee participants for their participation and time away from home.

CONCLUSION

Progress is being made on two fronts, the RF cable interface and the decoder interface. Interim standards for both committees can be expected by early 1986. Progress is slow and painful but essential if the customer/subscriber is to be provided with the maximum utility potential of the technology. These are long term solutions. But they will never arrive without heavy investment of energy and time in current committee work.

A CHANNEL DEPENDENT AUTHORIZATION METHOD FOR PAY-PER-VIEW AND IMPULSE PAY-PER-VIEW SERVICES

Thomas E. O'Brien

GENERAL INSTRUMENT CORPORATION

ABSTRACT

Authorization of pay services by channel number has until now been adequate because only one service is contained within each channel. Pay-per-view and impulse pay-per-view services require channel sharing, thereby placing greater demands on authorization control systems and increasing the complexity and cost of addressable set-top terminals. An improved authorization method is described and it is shown how, by introducing the concept of authorization by code number, dependence on the tuned channel can be eliminated. The equipment required to support this method is described and a pay-per-view example is given.

INTRODUCTION

Conventional pay TV authorization systems are characterized by a control computer located at the CATV office or headend, an access limiting device called a service encoder and a large number of addressable set-top terminals. The control computer maintains subscriber files which describe what services (channels) are authorized in each set-top terminal, and transmits the file contents by addressing each terminal to load its authorization table. This table consists of a simple memory wherein a single bit per available channel is set or clear to specify whether or not that channel is authorized. Services are assigned to a specific channel (i.e., HBO may be on channel 18). Changes to the authorization memory are usually initiated by the subscriber, who telephones the CATV office to request an upgrade or downgrade. A customer service representative (CSR) modifies the subscriber file (usually through a billing system) which results in the transmission of new information to the set-top terminal, thus changing the content of its table. This method is adequate because each channel is used for only one subscription service.

A pay-per-view (PPV) channel contains more than one service, with each program offering broadcast in a scheduled time slot. PPV services may be further broken down into shorter periods such as preview, purchasable and non-purchasable intervals and, with back to back events, a pre-purchase interval for the following program. In addition, it may be desirable for all terminals to be authorized for interstitials such as coming attractions, promotional fills and a program guide. The state of the channel authorization table may change several times through the duration of a program. While the bit per channel memory described above is clearly not adequate, two solutions are evident: 1) increase the data transmission to the rate necessary to address all terminals in a fraction of a second, 2) increase the authorization memory size to hold the time features of the program. Both of these solutions are impractical due to either bandwidth/ technology or cost constraints. It is the purpose of this paper to present an alternative method using code control, thereby avoiding the negative aspects of the obvious solutions.

CODE CONTROL

The conventional addressable set-top terminal contains a memory wherein individual bits correspond to channel numbers. The selected channel number addresses the memory to read out the associated bit. If set, the bit throws a switch to enable viewing the program (usually by permitting the descrambler circuitry to operate). This is illustrated in Figure 1. The information provided for descramble timing and control is carried in-band (normally audio carrier modulation) and decoded by other circuitry (not shown). The addressable controller maintains a cross reference list which equates each service to its channel number.

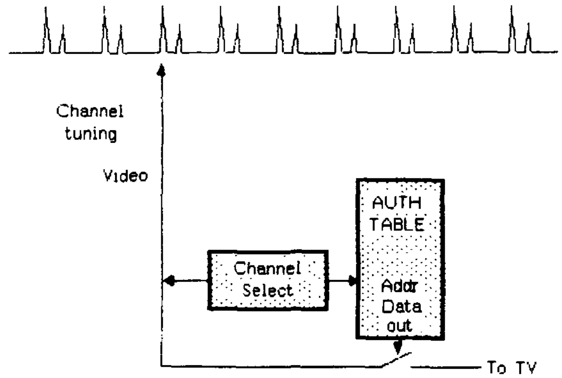


Figure 1 Authorization by channel

A code controlled terminal looks very similar as shown in Figure 2. In this case, however, the channel number is not used. Instead, each secured service has appended to it, a number called a "service code", which is carried in-band along with the existing descramble timing information. The service code addresses the memory to read out the authorization bit which, if set, throws the authorization switch as before. The addressable controller maintains a list equating each service to its assigned service code. The advantages of this approach will now be discussed.

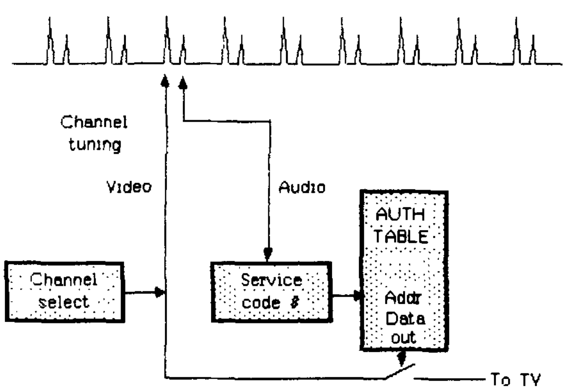


Figure 2 Authorization by service code

It is not necessary for the service code to be held constant, although it usually is for subscription services. Any encoded channel may be used for PPV services. An existing subscription service may be partitioned and sold separately, for example, by using one service code value from 12:00 midnight to 8:00 PM and another from 8:00 PM to midnight. By setting one service code value equivalent to "basic", all subscribers may be authorized for certain promotional information. A group of channels may be sold as a package by setting their service codes to the same value. The greatest benefit of this technique accrues with PPV services. Recall from the previous discussion the need to segment a PPV service into several time slots. A set of service code values may be used for this purpose, as shown in the PPV example in a later section.

As previously indicated, the service code is actually part of the descramble timing information carried in the TV signal. The value is inserted by the service encoder as directed by either front panel switches or remotely from the addressable control computer as shown in Figure 3. With the remote control feature, the addressable service encoder permits the addressable control computer to schedule and control services. The information sent to the set-top terminals via this path is not restricted to service codes. It should be service related, however, and may also contain the following:

- Service type (subscription or pay-per-view)
- Purchasable or not
- Morality rating
- Cost of purchasable service
- Encoding method
- Barker channel if unauthorized

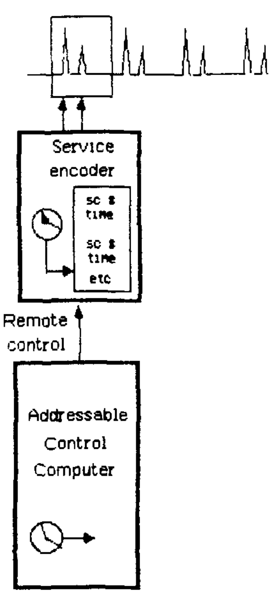
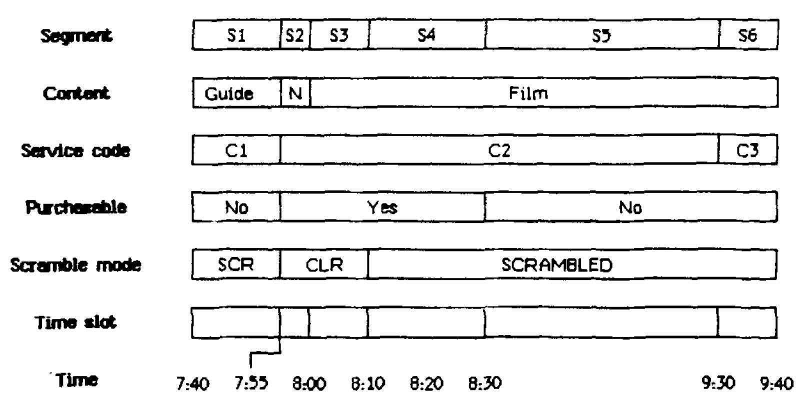


Figure 3 Remote controlled service encoder

Note that even this seemingly small amount of data may require significant transmission bandwidth at common program switchover times. Therefore, it is prudent to include a time controlled queue in the service encoder. Thus, the data for several time slots may be preloaded into the set of encoders for execution at pre-specified times, avoiding peak load bandwidth requirements. As a final point, it is evident that both the addressable control computer and the addressable service encoder need to understand time. The service encoders contain a battery backed real time clock which is periodically synchronized by the addressable control computer through a time message transmission.

PPV CONTROL

Armed with these new tools, a PPV control example will now be presented. In the following discussion, the program and interstitials are broken into time segments labelled S1 through S6 and service code values assigned C1, C2 and C3. A typical Hollywood film runs about one hour and 40 minutes. It is customary to run interstitials between films consisting of coming attractions, sales information, program guide, etc. For control purposes, these are included in the "program" schedule which is assumed to start at 7:40 PM and run two hours to end at 9:40 PM. It is also assumed that some part of the subscriber population is configured with store and forward set-top terminals, thereby permitting "impulse" purchase of the event. The "program" actually starts at the end of the previous event, which occurs at 7:40 PM. Assume further that there is a promotional barker channel to which unauthorized set-top terminals will tune when the subscriber attempts to tune a pay-per-view channel and is not already authorized. Refer to Figure 4. The first segment, S1 contains the program guide which runs for 15 minutes. During this time all subscribers are authorized to view a rolling list of services along with their associated cost and broadcast times. Blanket authorization may be accomplished either through use of a service code (C1) for which all subscribers have been previously authorized or by the clear mode (not scrambled). The system could have alternatively pre-authorized only a selected partition of subscribers, for example those who have impulse terminals. Segment 2 contains the "coming attractions", where scenes from the next program are shown to stimulate interest. The service code is set to C2 (the one actually used for the film) during this period to allow impulse purchase, however, the signal is sent using the clear mode, therefore all subscribers may view the picture. The program begins with segment 3 during which time the service code and mode are retained to provide a ten minute "preview", while allowing late comers the opportunity to purchase. A second advantage of the preview period is to allow more time for the system to respond to call in purchases from those subscribers without impulse terminals. The encoder is set to scramble during segment 4, while retaining the same



Note: N = "Whats next"

Figure 4 PPV control sequence

service code and purchasability attributes. During this segment, unauthorized subscribers will be able to view only the barker channel which should contain a rolling tutorial describing how to purchase the program. Segment 5 is included to terminate the ability to purchase the film. Set-top terminals may be outfitted with a display lamp which when lit, indicates a "purchasable event". This lamp will go off at segment 5 if the event has not already been purchased. This feature is a convenience to subscribers who may have tuned in late and, if they knew how much of the program has already elapsed, would probaby decide not to purchase it. Although segment 6 is not strictly necessary in this example, it is included for completeness. This segment is required to solve a somewhat elusive control problem which is described below.

Authorization by service code is not without disadvantages. A service code number may be used at any time on any channel, however, it must not be used for more than one program at any one time. Occasionally, due to service code value limitations or scheduling conficts, two or more programs on the same or different channels may be assigned the same service code. Under these conditions, subscribers authorized for one program would automatically be authorized for the others. Three global commands may be used to prevent this undesirable situation. The three commands are "set", "clear" and "copy" service code. During segment 5, the control computer issues a global "copy C2 to C3" command. All subscriber terminals which are authorized for C2 will now be authorized for C3 also. During segment 6 the service code is set to C3 after which the control computer issues the command "clear C2". This action occurs during the last few minutes of the program because it is unlikely that any terminals would be unpowered - thereby avoiding the downgrade of C2 - at this time. Since the command sequence is closely spaced, it is also unlikely that the terminals would hear the first command and not the second. The alternate service code, C3, may be any spare subscription code - not used for PPV - since it is only used for short, non-overlapping time intervals.

SUMMARY

A channel independent authorization method has been described. This method allows efficient pay-per-view control while avoiding the traditional bandwidth and cost intensive changes to conventional pay TV authorization systems. Programming capabilities include interstitials, program previews, impulse purchasing and global control of segmented authorization populations. This method should find interesting application as more cable system owners utilize pay-per-view programming as the next major CATV venture.

A TRAINING CATALOG

By Dana Eggert

United Artists Cablesystems Corp.

ABSTRACT

In a maturing cable industry, operating costs and expenditures tend to be more closely scrutinized so as to insure optimum cost-effectiveness. At the same time, employee productivity and quality of service should not be compromised.

Often, training is overlooked as both the day-to-day and long-term link between cost-effectiveness and quality and productivity.

Using a training topics matrix of available course material and desired results, this paper will discuss outside training sources and how they can be constructed into a highly cost-effective, custom-designed, individualized technical training program. Also included is a thorough, annotated catalog of training resources.

THE TRAINING PARADOX

The absence of CATV-specific technical training, either through in-house training departments or outside resources, is not a new problem to the technical-intensive industry. But at a time when rebuilds have subsided, pay services have plateaued, and operating systems are working harder to keep subscribers and upgrade their services, CATV technical training, and the costs associated with it, indeed becomes a paradox. While most companies are trying to scale back operating costs, at the same time, rising costs associated with outages, callback, and new complexities from VCR connections and competition from backyard dishes, as well as the new Communications Act of 1984 franchise renewal pressures require that cable companies pay particular attention to signal service quality and technical integrity. So instead of cutting back on training as an operating cost, many cable operators are discovering that more training commitment is necessary to lower operating costs, and that it is now a key ingredient not only in maintaining quality service, but also in providing motivation and support for technical employees, thereby affecting productivity and bottom-line profitability.

But, how much of the training responsibility is the company's? Will the company have to develop its own in-house training department and facilities to provide customized, quality training? What is the most cost-effective approach to training that also yields the desired results?

THE TRAINING COMMITMENT

The first step in any new training program should be the solid commitment by company management to encourage and promote training for all employees, technical and non-technical. Regardless of how many training dollars are spent by a company on its employees, if the participants do not perceive the company as an enthusiastic player and see some real attainable benefit to themselves, then those dollars are wasted because real learning through motivation will not occur. More importantly, companies should develop a written training commitment and policy stating exactly what management's responsibilities are and how the company will fund the program regardless of how the training program is structured.

> Example: It is the policy of the Company to encourage employees to enroll in accredited educational institutions and/or special training courses designed to improve on-the-job performance and help prepare the individual for greater responsibilities.

Enrollment in such courses may be at the recommendation of either the Company or the employee. However, in all cases where reimbursement is requested, the course must be approved by the employee's department head and the system manager prior to enrollment.

If the Company requires the employee to take the course, then 100% of the course fees, plus books and out-of-town travel are paid by the Company. If the course is directly applicable to the employee's job, the Company will reimburse the employee for 100% of the course fees upon successful completion of the course. Other courses, which bear some relationship to the employee's job or to his/her career development in the Company, will be reimbursed for 75% of course fees upon successful completion of the course.

Along with this written statement of commitment, management must also determine the nature or structure of the training program: an in-house training department, vocational schools, or an eclectic approach using outside resources.

THE ECLECTIC APPROACH

The ultimate goal in any technical training program is to develop the technical employee through training and experience to the company-desired standard of performing the current job as well as to prepare selected employees for added responsibilities at higher levels. There are several ways to structure and develop a technical training program geared to meet this goal. A few companies have chosen to develop a complete in-house, self-supported training program requiring its own training center and staff. Others may take advantage of vocational schools or local colleges for CATV technical training while still others may completely depend on correspondence programs or contracted in-house presentations. Although all of these approaches have merit, at this point in the industry, an eclectic approach, or the piecing together of a training program from a variety of sources, may indeed prove to be the most cost-effective while producing more than adequate and acceptable results. In fact, this approach to technical training draws from all of the above resources and combines these into a program to fit both the company's and student's needs.

The advantages of this method are many. For one thing it does not require the kind of full time staff or financial investment as that of an in-house training department. Secondly, by using outside sources, the training content should be continually updated to fit the needs of the industry. Third, the employees are not away from their jobs for extended periods as is required for vocational school attendance, maintaining productivity while learning specific on-the-job skills. Also, this approach takes best advantage of the "none of us are as smart (in training approaches, materials, strengths, etc.) as all of us together. Finally, and most importantly, this training approach allows the most flexibility for the student not only in subject areas but in timing as well.

TRAINING SOURCES

Many sources of technical training already exist and are the foundation of this type of training program. Sources include correspondence schools and self-study programs, local and regional short seminars, contracted in-house presentations, local community college evening courses, and other CATV operating companies' training centers. In addition, training topics range from CATV specific and electronics to management and data communications, all relevant to the progression of technical personnel.

The matrix below lists training sources by company name and indicates the respective subject or areas of training. For more information about the specifice sources, see the "Training Resources" list included in this paper.

TRAINING TOPICS MATRIX

NAME	CATV TECHNICAL	ELECT-RONICS	ENGR	COMPUTER	DATA COMM	CAD	FIBER OPTICS	VIDEO PROD	MGT/SUPERV	CUSTOMR SERVC	SAFTY	PRODUCT SPECIFIC
AMA-EXTENSION INSTITUTE				X					X			
AMERICAN INSTITUTE				X								
AMERICAN MEDIA									X	X	X	
ANN ALVIS TRAINING										X		
ARTHUR ANDERSEN/EDUC SERV									X			
ATC NATIONAL TRAINING CENTR	X											
AUBREY DANIELS & ASSOC									X			
BERGWALL TRAINING SYSTEMS		X		X		X			X		X	
BLONDER-TONGUE	X											
C-COR ELECTRONICS	X											
CATV TECHNICAL TRAINING SEMIN.	X											
CENTER FOR ADV PROF EDUC					X							
CENTER FOR CREATIVE LEADERSHIP									X			
CHILLICOTHE VOCATIONAL		X										
CLEVELAND INST. OF ELECTRONICS		X										
DAKOTA COUNTY VOCATIONAL	X											
DARTNELL									X	X		
DATA-TECH INSTITUTE				X	X							
DATACOMMUNICATIONS					X							
DATAPRO RESEARCH CORP					X							
DIGITAL EQUIP./ EDUC SERV				X								X
DSI MICRO INC				X					X			
DUN & BRADSTREET BUSN EDUC SRV									X			
EAGLE SEMINARS								X				
EAST BAY SKILLS CENTER	X											
ENTRAINMENT										X		
ESSEX COUNTY COLLEGE		X										
GENERAL SERVICES ADM		X									X	
GEORGE WASHINGTON UNIV			X									
GILBERT ENGINEERING	X											X
HAINES ASSOC.									X			
HARVARD BUSN RVW-REPRINT SVC									X			
HEATH COMPANY		X										
HENKELS & MCCOY	X										X	
HEWLETT-PACKARD												X
HUGHES MICROWAVE ASSOC.	X											X
ICS-INTEXT		X										
IEEE SERVICE CENTER			X	X					X			
INFORMATION GATEKEEPERS,INC							X					
INST ADV TECHN/CONTROL DATA				X	X				X			
INST FOR PROFESSION EDUC			X	X					X			
INTERFERENCE CONTROL TECHN.			X									
JERROLD	X											
KNOWLEDGE INDUSTRY PUBLICTN								X				
LOI INSTITUTE									X			
MAGNAVOX CATV SYSTEMS INC	X											
MCGRAW-HILL TRAINING SYSTEMS									X			
MERCER COUNTY COLLEGE	X		X					X				
MIDDLESEX COMMUNITY COLLEGE	X							X				
NCTI	X							X				
NEW YORK UNIVERSITY						X		X				
NORTH TEXAS STAT UNIV				X					X			
NRI SCHOOL OF ELECTRONICS		X		X								
OMEGA SCHOOL OF COMMUN	X	X										
PADGETT-THOMPSON									X			
PHILLIPS PUBLISHING INC,	X				X							
PRYOR RESOURCES									X	X		
RESOURCE									X	X	X	
SCTE	X								X			
SHELDON SATIN ASSOC										X		
SMU-COX SCHOOL OF BUSINESS			X									
SOFTWARE INST OF AMER.					X							
SOUTH OKLA CITY JUNIOR COLLEGE		X										
STAT-A-MATRIX INSTITUTE			X									
TELEOMETRICS INTERNATIONAL									X			
TELESTRATEGIES					X							
UCLA EXTENSION			X	X	X				X			
UNIV COLLEGE - CINNCINATI	X								X			
UNIV OF MICHIGAN/ SCH BUSN AD									X			
WADENA AREA VOCATIONAL	X											
WISCONSIN INDIANHEAD TECHN	X											

Figure 1. Training Topics Matrix

As is obvious from the matrix, there are many training resources to draw from and many topics to choose from in designing an eclectic training program, and this matrix is still not exhaustive. By using this matrix one can easily design any form of needed short-term or long-term training program not necessarily uniform for all employees, but individualized for each technical employee to address specific needs.

A basic, boiler-plate technical training program can more than likely be applied in most circumstances with only slight variations. The more complete and thorough the basic program is, the more it will cost, but the more flexible it will be as well. Following is an example of a very basic training program designed to be applicable to almost all CATV technical employees beginning with Installer and following all the way through to Chief Engineer.

Basic Training Program Boilerplate

SOURCE NAME	TRAINING TOPIC	FORMAT	TIME REQUIRED/ ALLOWED	PRICE
NCTI	Installer	Self-study	2 years	$240
Local	CPR	Seminar	2 days	$75
ICS	Technical Mathematics	Self-study	1 1/2 yrs	$330
NRI	Specialized Communications Electronics	Self-study	2 years	$835
NCTI	Technician	Self-study	2 years	$500
Magnavox	Mobile Technical Training Seminar	Workshop	3 days	$300
AMA	Writing for Success	Self-study	6 months	$95
NCTI	Chief Technician	Self-study	2 years	$610
Hughes Microwave	Microwave Basics	Workshop	5 days	$0
Datapro	Data Communications I	Seminar	3 days	$695
Jerrold	Special Technical Session	Workshop	4 days	$295
IEEE	Management Program	Self-study	1 year	$400
Datapro	Data Communications II	Seminar	3 days	$695
SCTE	BCT/E Certification	Self-study	2 years	$50
AMA	Time Management	Self-Study	6 months	$95
Cleveland Inst.	AAS in Electronics Engineering Technol.	Self-study	4 years	$3,000
UCLA	The Technical Mgr in a Dynamic Envir	Seminar	3 days	$875
				========
				$9,090

Figure 2. Basic Training Program Boilerplate

Following this 18 year program, the company would spend roughly $5Ø5 per student annually, depending on the student's progress and interest in advancing. A more complete training program, Figure 3., requires the company to make an initial investment of $2555 for audio and video training tapes.

Training Program Boilerplate

SOURCE NAME	TRAINING TOPIC	FORMAT	TIME REQUIRED/ ALLOWED	PRICE
NCTI	Installer	Self-study	2 years	$240
SCTE	"Confident Climbing I & II"	Videotape	60 minutes	$150
SCTE	"Coaxial Cable Basics"	Videotape	30 minutes	$75
SCTE	"Safety Awareness"	Videotape	30 minutes	$75
SCTE	"Diagnosing Common Cable Faults"	Videotape	30 minutes	$75
SCTE	"Cable Handling & Installation"	Videotape	30 minutes	$75
Gilbert	"Connectors"	Videotape	30 minutes	$50
Local	CPR	Seminar	2 days	$75
ICS	Technical Mathematics	Self-study	1 1/2 yrs	$330
Pryor Resources	Customer Relations	Audiotapes	6 days	$90
American Media	"Take Care" (Customer Relations)	Videotape	45 minutes	$500
NRI	Specialized Communications Electronics	Self-study	2 years	$835
SCTE	"dB and dBmV"	Videotape	30 minutes	$75
SCTE	"SLM Basics"	Videotape	30 minutes	$75
SCTE	"SLM: Errors & Accuracy"	Videotape	30 minutes	$75
NCTI	Technician	Self-study	2 years	$500
SCTE	"NTSC Video Test Signals I & II"	Videotape	60 minutes	$150
Magnavox	Mobile Technical Training Seminar	Workshop	3 days	$300
SCTE	"Video Waveform Measurements"	Videotape	30 minutes	$75
SCTE	"Overhead Lines & Backfeed"	Videotape	30 minutes	$75
AMA	Writing for Success	Self-study	6 months	$95
Resource, Inc.	"Bucket Rescue"	Videotape	30 minutes	$110
NCTI	Chief Technician	Self-study	2 years	$610
Hughes Microwave	Microwave Basics	Workshop	5 days	$0
SCTE	"RF Sweep Generator Applications"	Videotape	30 minutes	$75
Pryor Resources	Basic Supervision I & II	Audiotape	2 weeks	$180
Datapro	Data Communications I	Seminar	3 days	$695
Jerrold	Special Technical Session	Workshop	4 days	$295
IEEE	Management Program	Self-study	1 year	$400
Datapro	Data Communications II	Seminar	3 days	$695
SCTE	BCT/E Certification	Self-study	2 years	$50
AMA	Time Management	Self-Study	6 months	$95
American Media	"Time Trap"	Videotape	45 minutes	$500
Cleveland Inst.	AAS in Electronics Engineering Technol.	Self-study	4 years	$3,000
SCTE	"Developing a Preventv Mainten. Prog"	Videotape	30 minutes	$75
UCLA	Th[illegible]ical Mgr in a Dynamic Envir	Seminar	3 days	$875
				========
				$11,645

Figure 3. Training Program Boilerplate

This investment divided over the same time frame comes to $141 per year for the purchase of training tapes, and $141 divided by the number of technical trainees most likely will not be over $3Ø annually. This raises the annual amount of training dollars spent per student to approximately $535. The cost difference, then, between a very basic training program and a more thorough program is minimal, but the difference in the results could be significant. The company now has a permanent training library available both to new employees and students for first time viewing or listening as well as experienced employees for reviewing and retraining purposes.

The flexibility and value of the eclectic approach to address a system's wide variety and changing training requirements by general or technical managers is obvious in these limited examples. It is beyond the scope of the intent of presenting the training matrix and full training listing to dramatize further specific application examples. It is up to interested systems to determine for themselves the best approaches and combinations of the resouces listed and categorized here for their own best general or specific training programs.

CONCLUSION

The days of the midas touch for the cable industry have since passed and as CATV technology becomes increasingly complex, cable systems must pay closer attention to the training function as a bridge between cost-effective operations and long-term quality of service. Using an eclectic approach to develop a training program may prove to be the most cost-effective method for the company as well as most beneficial, flexible, and productive for the technical trainee. With the help of the training matrix and thorough listing of training resources, companies should easily be able to piece together their own basic training program to meet their specific needs and desired results.

TRAINING RESOURCES

Ann Alvis Training, Inc.
1701 1st Ave W
Bradenton, FL 33505
813-748-3809

Ann Alvis provides in-house training in customer service, customer relations, communication skills, direct sales, management relations, etc. Ann presents activity-oriented three hour training sessions individually developed and designed specifically to fulfill the needs of the participants to produce the desired results. Fees include an $85 hourly rate during actual training as well as expenses.

American Institute
Carnegie Building
55 Main Street
Madison, NJ 07940
212-377-7400

The American Institute offers computer-oriented, regional two to four day seminars. Course titles include, "Writing & Using Macros for Lotus 123," "Project Management on the Personal Computer," "Data Communications: An Intensive Introduction," and "Hands-on Troubleshooting Data Communications Systems & Networks." Tuition fees range from $595 to $895. CEU's are awarded.

American Management Association
Extension Institute
135 West 50th Street
New York, NY 10020
212-903-8040

AMA Extension Institute offers 87 independent study courses in five general categories including General Management Skills (time management, technical writing, basic supervision, etc.), Management and the Computer, Marketing Management, Manufacturing Management, Service Organization Management, and Managerial Finance and Control. AMA-EI allows these courses to be taken individually or in a combined program resulting in a Certificate in Business Management. Courses are self-regulated; correspondence tests are included. Nonmember price per course is $94.95.

American Media
1454 30th Street
West DesMoines, IO 50265
800-262-2557

American Media offers for purchase a wide variety of management, customer service, and safety training videotapes. The cost for each tape averages $500.

Arthur Andersen & Co.
Educational Services
1405 North Fifth Ave.
St. Charles, IL 60174
800-874-4449

Regional one to four day seminars cover many aspects of management. General management courses include general supervision, business writing, time management, project management, etc. Seminar tuition ranges from $175 to $600. In-house, customized training programs are also available.

ATC National Training Center
2100 South Hudson
Denver, CO 80222
303-753-9711

On-site training provided by ATC training staff. Courses include Installer, Technician I, and Technician II. Prerequisite training from Cleveland Institute of Electronics is necessary for both technician courses. Excluding time involved for correspondence CIE work, each on-site class runs about 10 days. Tuition is approximately $1000 per course; transportation, room and board, and prerequisite courses not included.

Aubrey Daniels & Associates
3531 Habersham at Northlake
Tucker, GA 30084
404-493-5089

Regional one day human relations seminars including "How to Talk to People," and "How to Work with People in a Positive Way." Seminar fees range from $195 to $210.

Bergwall Training Systems, Inc.
106 Lindbergh Blvd
Uniondale, NY 11553
800-645-3565
516-222-1111

BTS offers a variety of standard courses for use as in-house training. Courses can also be used as self-regulated indepedent study. Course topics include business writing, basic accounting, BASIC programming, fleet maintenance, drafting, CAD, basic electricity, basic electronics, digital electronics, etc. BTS also provides custom designed training programs.

Blonder-Tongue Laboratories
One Jake Brown Road
Old Bridge, NJ 08857
201-679-4000

BT offers a two day regional seminar on MATV, CATV, and SMATV technologies for $125 per person. Interested parties should contact local offices for scheduled seminars in those areas.

C-Cor Electronics Inc.
60 Decibel Road
State College, PA 16801
814-238-2461

C-Cor holds several regional three day technical seminars for CATV Technicians throughout the year. Seminars cover system basics, adjustment of amplifier levels, system performance, system upgrade and problems, along with specific, hands-on C-Cor equipment training. Seminar registration is $100.

CATV Technical Seminars
PO Box 9893
Alexandria, VA 22304
703-823-6522

The three day regional seminar offers CATV technical basics including cable transmission systems, equipment, distortions, amplifier technology, microwave applications, satellite technology, system design, maintenance and operation etc. Advance registration fees are $450.

Center for Advanced Professional Education
1820 E. Garry Street, Suite 110
Santa Ana, CA 92705
714-261-0240

Two to three day seminars focus on data communications. Seminars are offered regionally for $645 to $695. CEU's are awarded.

Center for Creative Leadership
5000 Laurinda Drive
PO Box P-1
Greensboro, NC 27402-1660
919-288-7210

The Center for Creative Leadership provides free literature and information on leadership and management skills and improvement techniques. Also available without charge is a subscription to Issues & Observations by contacting the center.

Chillicothe Area Vocational Technical School
1200 Fair Street
Chillicothe, MO 64601
816-646-3414

The school offers a two year Electronics Technician program (1080 hours). The day-time only program includes theory, troubleshooting, circuits, etc. Tuition for the first year is $1000 and $2000 for the second year.

Cleveland Institute of Electronics
1776 East 17th Street
Cleveland, OH 44114
216-781-9400

CIE offers independent, self-study electronics training including FCC License, Electronics Technology, Electronics Engineering, Electronics Engineering and Advanced Troubleshooting, as well as a comprehensive Associate in Applied Science in Electronics Engineering Technology program.

Dakota County Area Vocation Technical Institute
145th Street & Akron Road
PO Drawer K
Rosemount, MN 55068

The school offers a 20 month CATV Technician program focusing on test equipment, amplifier technology, basic construction, antenna theory, etc. Tuition assessed per day. All courses offered during the day.

Dartnell
4660 Ravenswood Ave.
Chicago, IL 60640
312-561-4000

Dartnell sells or rents management, sales and customer service video training aids. Each training videotape or film is 20 to 30 minutes. Rental fees are $140 and purchase prices range from $400 to $700.

Data-Tech Institute
Lakeview Plaza
PO Box 2429
Clifton, NJ 07015
201-478-5400

Data-Tech offers regional one to three day seminars focusing on data communications and software specific programs. Course titles include "Data Communications: A Complete Overview," and "Advanced Application Techniques: Using Lotus 123 Macros and Functions." Some courses are available as in-house programs and can also be customized for specific needs. Tuition fees range from $395 to $795.

DataCommunications
Special Projects Conference Management Center
c/o Information>Breakthroughs, Inc.
445 West Main Street
Wyckoff, NJ 07481
201-891-8405

Regional two to five day seminars focusing on data communications are offered from $595 to $1400. Course titles include "Comprehensive Course in Data Communications," "X.25 and Packet-Switched Networks," "Integrated Data & Voice Networks/ISDN," etc.

Datapro Research Corp.
1805 Underwood Blvd.
Delran, NJ 08075
800-257-9406

Regional two to three day seminars are offered on data communications and telecommunications. Titles include Data Communications I & II, Transmission Technologies, Data Network Design & Performance, Telecommunications I & II, etc. Tuition fees range from $695 to $795. Catalog available by writing.

Digital Equipment Corp.
Educational Services
Seminar Programs BUO/E58
12 Crosby Drive
Bedford, MA 01730
617-276-4949

Digital offers regional one to four day computer training sessions on their own equipment and software. Tuition ranges from $250 to $900.

DSI Micro, Inc.
770 Broadway
New York, NY 10003
212-475-3900

DSI Micro offers self-study training packets on management skills, basic computer operation as well as more advanced computer operations. The computer-based training kits include training diskettes and guides; some include video training tapes as well. Prices of kits range from $39.95 to $450. Catalog available by writing.

Dun & Bradstreet Business Education Services
PO Box 803
Church Street Station
New York, NY 10008
212-312-6880

A one day seminar on the basics of supervision is offered regionally for $125. CEU's are awarded.

Eagle Seminars
2612 Croddy Way
Santa Ana, CA 92704
714-777-3488

Eagle offers a regional one day professional audiovisual production seminar from slides and multi-image to video to new technologies such as interactive videodisc and videoconferencing. Seminar tuition is $165. CEU's are awarded.

East Bay Skills Center
1100 67th Street
Oakland, CA 94608
415-658-7356

The center offers two CATV technically-oriented training programs. The six-month program focuses primarily on installer functions including installation, splicing, basic construction, pole climbing and troubleshooting. The nine-month program covers the same material as well as design, antenna theory, testing and measurements, etc. Courses are offered during the day with no tuition cost to the student.

Entertrainment
PO Box 7240
Portland, ME 04112
207-774-3307

Entertrainment offers in-house customer service and human relations training. Topics covered include the current basic and pay schedules, handling irrate customers, telephone etiquette, and self-esteem in relation to job satisfaction. Sessions are one day and cost $125 per person as well as expenses for the trainer, Steve Broydrick. Steve also conducts a pre-training on-site visit to determine specific areas of need and develops training agendas to fit those areas. Minimum attendance is 16.

Essex County College
303 University Avenue
Newark, NJ 07102
201-877-3274

The college offers a two-year associate degree program in broadcast technology and operations. Courses are offered during the day at $34.00 per credit hour.

General Services Administration
National Archives and Records Service
National Audiovisual Center
Washington, DC 20409
800-638-1300

A large collection of audio/visual training aids is available through the General Services Administration in several formats including 2 x 2 slides with audiocassette, 16mm films and videotape. Subjects range from agriculture to surgery. In the electronics category, 184 A/V programs are available, and many more in safety. All aids are available to rent or purchase at a relatively low cost; a 70 minute videotape can be purchased for $160. Catalog available by writing.

George Washington University
Continuing Engineering Education Program
Washington, DC 20052
800-424-9773
202-676-6106

GWU offers three to five day engineering courses on a wide variety of subjects such as data compression techniques, frequency hopping signals and systems and many more. All courses are held at the university. Room and board are not provided on campus. Tuition costs range from $515 to $920. Catalog available by calling or writing.

Gilbert Engineering
5310 West Camelback Road
Glendale, AZ 85310
800-528-5567
602-245-1050

Gilbert offers both technical seminars and training videotapes. The tapes focus on proper installation and application of their whole line of connectors. Videotape purchase prices range from $25 to $60.

Haimes Associates, Inc.
708 South Washington Square
Philadelphia, PA 19106
215-922-1617

Haimes offers regional two-day EEO seminars titled, "EEO: What You Need to Know" covering legal requirements, discrimination, and litigation. Tuition is $725. Haimes also has available for purchase a 50 minute EEO video training tape for $750. The tape can be previewed for five days for $65.

Harvard Business Review
Reprint Service
Soldiers Field
Boston, MA 02163
617-495-6192

HBR offers reprints of published individual management articles for a minimal fee, $1.00 per reprint. Other services offered include the reprinting and binding of custom selected groups of articles for in-house training purposes. In addition, HBR offers an on-line database service with more than 7000 HBR articles, indexed and abstracted for easy reference.

Heath Company
Heathkit
Benton Harbor, MI 49022
800-253-0570
616-982-3411

Heathkit offers electronic devices in kit form with assembly required such as oscilloscopes, frequency counters, multimeters, spectrum analyzers, noise generators and many more that can be used in conjunction with electronics training programs. In addition, Heathkit offers correspondence amateur radio courses including Novice, General License, and Advanced Class Radio License courses, all under $60. CEU's are awarded for completion of the General License and Advanced courses. The Heathkit catalog is available on-line through CompuServe by typing GO HTH at any "!" or "OK" prompt.

Henkels & McCoy
Jolly Road
Blue Bell, PA 19422
215-283-7600

Henkels & McCoy offers CATV technical training courses both as in-house programs or through state agencies on a rotational basis. The courses offered are CATV Installer, CATV Installer Technician, and CATV Draftsman/Strand Mapper. Sources for these courses rely heavily on NCTI information. Schedules of government-funded courses are available from H&M by calling Jerry King, Western Training Manager, at 618-252-5311, or Evan Baker, Eastern Training Manager, at 215-283-7829. In-house training programs can be customized for specific needs and draw from 42 separate H&M categories at an average cost of $1500 for a five day program. Prices varies depending on class size and program.

Hewlett Packard
W-120 Century Road
Paramus, NJ
201-265-6800
Or Nearest Sales Office

HP offers many product-specific courses throughout the North American continent at their 42 training centers. For detailed course descriptions, write for the HP Customer Education, Consulting, and Implementation Services Planning Guide, the North American Customer Training Schedule for Computer and Instrument Products, and the North American Instrument Training Catalog. Tuition fees range from $125 to $2950 and courses run from one to five days.

Hughes Microwave Communications Products
PO Box 2999
Torrance, CA 90509
213-517-5276

Hughes offers 4 1/2 day seminars on product-specific microwave equipment and procedures, channel configuration, and troubleshooting. The seminar is available at no charge to the participants. All seminars are conducted in Torrance, CA. Daily lunches and one evening meal are provided.

ICS-Intext
Continuing Education Division
Oak and Pawnee Streets
Scranton, PA 18515
717-342-7701

ICS offers correspondence self-study training on a wide-variety of subjects with special emphasis on math, and electricity and electronics. ICS offers pre-arranged courses, but will customize any group of lessons into new courses. Videotapes and training aids (e.g. electrical experiment kits) are also available. The cost of a course depends on the number of lessons, each lesson costing $23.

IEEE Service Center
445 Hoes Lane
Piscataway, NJ 08854-4150
201-981-0060

IEEE offers individual learning packages on digital signal processing, spread spectrum signal and systems and advanced microprocessors. Each package includes a textbook, study guide, and audiocassette. In addition, some packages include optional experiments, workbooks, and floppy diskettes. Non-member prices range from $62.95 to $325. IEEE also offers a self-study management program in five sections including team building, project management, business writing, basic supervision, and building memory skills, each of which can be purchased separately for $99.95 or as a five-group program for $399.80. CEAU's are awarded.

Information Gatekeepers Inc.
214 Harvard Ave.
Boston, MA 02134
617-232-3111

Information Gatekeepers sponsors seminars, expositions, and reference materials on fiber optics. Seminars include measurement and testing of fiber optics, system designs, digital switching, etc. Fees range from $445 to $695. Seminars are generally held in the Boston vicinity and are from one to two days.

Institute for Advanced Technology
Control Data Business Advisors
6003 Executive Blvd.
Rockville, MD 20852
800-638-6590

Over 80 regional seminars are offered in the area of data communications, database management, software engineering, personal computers, management/supervisory development, marketing and sales, etc. Fees range from $195 to $995 and are from one to five days. Also available are management training videocassettes for $95 and personal computer videocassettes for $195 and $295.

The Institute for Professional Education
1515 North Court House Road, Suite 303
Arlington, VA 22201
703-527-8700

IPE offers regional two to five day seminars in statistics, management, simulation and modeling, personal computers and computer science. Tuition fees range from $710 to $1250. In-house and customized programs are also available.

Interference Control Technologies
Don White Consultants Inc, Subsidiary
State Route 625, PO Box D
Gainesville, VA 22065
703-347-0030

A three-day regional seminar on grounding and shielding with an optional fourth day workshop using CAD is offered for $815 plus $235 for the workshop. CEU's are awarded.

Jerrold Division
General Instrument Corp.
2200 Byberry Road
Hatboro, PA 19040
800-523-6678

Jerrold offers a four day "hands-on" CATV technical seminar covering the fundamentals of cable, headends, system design-trunk and feeder, operation and maintenance, pay systems, and computer controlled systems, PPV systems, stereo systems, status monitoring systems, proof of performance, and sweep. Tuition is $295.

Knowledge Industry Publications, Inc.
701 Westchester Ave.
White Plains, NY 10604
800-431-1880
914-328-9157

Knowledge Industry offers regional video-oriented seminars including using and maintaining video equipement, editing techniques, directing, camera operations, field production, managing a video staff, etc. Seminars range from one-half to two days and cost $140 to $465. Also available is a four day production workshop for $850. A catalog of reference materials is available as well.

Learning Dynamics Institute, Inc.
PO Box 323

Needham, MA 02192
800-225-1558

LDI offers a one day seminar on listening and memory skills. Participants receive a workbook and audiocassette on communicating clearly. Seminar tuition is $185 with special discount rates for group attendance. The seminar is also available for in-house presentation.

Magnavox CATV Systems, Inc
100 Fairgrounds Dr.
Manlius, NY 13104
315-682-9105

Magnavox offers a three part "hands-on" CATV technical course including basic theory, pratical application, and hands-on training. Magnavox uses its unique mobile technical training van in conjunction with a standard classroom format. Tuition is $300 for the three day seminar.

McGraw-Hill Training Systems
PO Box 641
Del Mar, CA 92014
619-453-5000

The MGH Supervision Series offers a ready-made in-house supervisory training program in four training modules including fundamental skill building, interpersonal skill building, functional skill building and management orientation. Each segment of the module provides a trainer's guide, participant workbooks, videocassette and audiocassettes. The complete supervision series including all segments of all modules costs $11,992.50. Each segment can be purchased separately, discounts applying to quantity purchases.

Mercer County Community College
1200 Old Trenton Road
Trenton, NJ 08690
609-586-4800

Mercer College offers an Associate Degree Program in Telecommunications Technology including courses in radio, television, CATV technology, satellite and microwave technology, broadcast and cable design, and radio, television, and CATV engineering. Tuition is $26 per credit hour. Financial assistance is available.

Middlesex Community College
100 Training Hill Road
Middleton, CT 06457
203-344-3052

Middlesex College offers an Associate Degree program in Cable Telecommunications. The two year program focuses on CATV technical practices, video production, graphics, duplication, etc.

National Cable Television Institute
PO Box 27277
Denver, CO 80277
303-761-8554

NCTI offers correspondence, self-study CATV training programs including Installer, Technician, Chief Technician, System Tech I & II, Advanced Technician, Master Technician, and TV Production. Each lesson is followed with an exam, and successful completion of a final exam is now required before certification. Tuition ranges from $115 to $760 with discounts applied to repeat students. Students also receive at no charge Cable Tech, an NCTI publication.

New York University
School of Continuing Education
PO Box 1206
Stuyvesant Station
New York, NY 10009
212-598-7064

NYU offers a certificate program in Video Management and Technology through the successful completion of six courses including The Video Marketplace, A Guide to the Electronic Media, and any four of six elective courses. Courses run from four to ten sessions and cost $230 or $275. Also available through Continuing Education are two day seminars on CAD and drafting, AUTO-CAD, and selecting and evaluation CAD systems for $450.

North Texas State University
Professional Development Institute
PO Box 13288, NTSU
Denton, TX 76203-3288
817-565-2483

PDI offers a variety of seminars including project management, basic supervision, sales, personal computer basics, Lotus 123 and DBase II & III, business writing, time management, etc. Tuition ranges from $495 to $1190. Sessions are from one to four days. Also available are audiocassette management training programs as well as in-house programs.

NRI School of Electronics
3939 Wisconsin Ave., NW
Washington, DC 20016
202-244-1600

NRI's correspondence study curriculum includes 16 courses with emphasis in electronics and communications. Titles include "Basic Electronics," "Electronic Technology," "Communications Electronics," "Data Communications," etc. Tuition ranges from $470 to $2435. Financing is available.

Omega School of Communications
548 N. Lake Shore Drive
Chicago, IL 60611
312-321-9400

The Omega School offers a 10 week FCC License Program, an Installer Program and a Cable Television Technology Program. All courses are offered during the day, evenings and Saturdays. Contact Pat Ehrhart for registration information.

Padgett-Thompson
Padgett-Thompson Building
PO Box 8297
Overland Park, KS 66208
800-255-4141

A one-day leadership seminar is offered regionally for $98.

Phillips Publishing, Inc.
2811 Montrose Road
Potomac, MD 20854
301-340-2100

PPI offers two day regional data and telecommunications seminars geared toward the non-technical manager. Titles include "Fiber Optics Technology for the Non-Technical Manager," and "Satellite Technology for the Non-Technology Manager." Tuition is $595. In-house programs are also available.

Pryor Resources, Inc.
Audio Cassette Education Division
2000 Johnson Drive
PO Box 2951
Shawnee Mission, KS 66201
800-255-6139

Pryor Resources offers audiocassette management training programs including basic supervision, customer relations, management skills for the technical manager, etc. Six tape programs cost $90.

Resource, Inc.
14007 North Dale Mabry
PO Box 271570
Tampa, FL 33688
813-961-4290

Resource offers a library of audiovisual training materials for self or in-house study. Materials can be rented or purchased. Related subjects include safety and customer relations. Individual videocassettes cost $110 to $400.

Sheldon Satin Associates, Inc.
135 William Street
New York, NY 10038
212-267-3560

Satin Associates provide customized training programs for in-house presentations focusing on customer service and relations. Prices vary according to the number of in-house trainers and participants.

Society of Cable Television Engineers, Inc
PO Box 2389
Westchester, PA 19380
215-363-6888

SCTE sponsors the BCT/E Certification Program designed specifically for CATV Technicians and Engineers. Participants are tested in seven areas including Signal Processing Centers, Video and Audio Signals and Systems, Transportation Systems, Distribution Systems, Data Networking and Architecture, Terminal Devices, and Management, Professionalism and Ethics, and must satisfy specified requirements in addition to successful exam completion. SCTE also offers numerous CATV training aids including publications and manuals, and videotapes.

Software Institute of America, Inc.
8 Windsor St.
Andover, MA 01810
617-470-3880

SIA sponsors data communications, regional, two to four day seminars. Tuition ranges from $395 to $795.

South Oklahoma City Junior College
7777 S. May Ave.
Oklahoma City, OK 73159
405-682-1611

The SOCJC Communications Department offers an Associate Degree program in Electronic Technology. Two elective courses in CATV electronics can be incorporated into the program.

Southern Methodist University
Edwin L. Cox School of Business
Management Center
Dallas, TX 75275
214-692-3255

SMU offers a two day seminar in various Texas locations on Statistical Quality Control. Course fee is $495.

Stat-a-Matrix Institute
2124 Oak Tree Road
Edison, NJ 08820
201-548-0600

Stat-a-matrix offers two to five day regional seminars focusing on statistics, quality assurance and engineering, and reliability. Tuition fees range from $695 to $1095.

Teleometrics International
1755 Woodstead Court
The Woodlands, TX 77380
800-527-0406

Teleometrics provides a training program titled "People Skills for Middle Managers" to be presented as an in-house program. Public presentations are available to review the program.

Telestrategies
1355 Beverly Road
McLean, VA 22101
703-734-7050

Telestrategies offers regional two to three day telecommunications seminars. Topics include basic technologies and system concepts in the Local Exchange System, specialized common carrier networks, CATV, communications satellite systems and data communications products and services. Tuition ranges from $795 to $1095.

UCLA Extension
PO Box 24901, Dept. K
Los Angeles, CA 90024
213-825-1047

UCLA offers an entire series of Engineering Short Courses in the areas of Aerospace, Applied Mathematics, Chemical, Civil, Computer Science, Electrical and Electronics Engineering, Engineering Management, and others. Electrical/Electronics course titles include "Modern Data Transmission," "Modern Microwave Measurements and Applications," "Optical Interference Coating Technology," "Program and Project Management: Principles and Practice," "The Technical Manager in a Dynamic Environment," and more. Courses are offered at or near the UCLA campus and are from four to five days. Tuition ranges from $795 to $975. CEU's are awarded.

University College
University of Cincinnati
ML 47
Cincinnati, OH 45221
513-475-3551

The University offers a two year Associate Degree program emphasizing cable management but with some focus on lab technician and distribution technician functions. Courses are available during the day and tuition is $637 per quarter for Ohio residents.

The University of Michigan
School of Business Administration
Executive Education Center
Ann Arbor, MI 48109-1234
313-763-1000

The University offers various management programs in accounting, corporate strategy, general management, labor relations, marketing, personnel, training, etc. All sessions are held on campus and are from three to five days. Tuition fees range from $970 to $2200 and include tuition, books, instructional materials, living accomodations, and all meals.

Wadena Area Vocational Technical Institute
PO Box 267
405 SW Colfax Ave.
Wadena, MN 56482
218-631-3530

WAVTI offers a 20 month Cable Television Technology program focusing on basic electronics and CATV installations the first year, and construction, test equipment, headends, antenna theory, satellite earth stations, etc. the second year. Tuition for Minnesota residents is $1100 for the first 9 months and $1347 for the next 11 months. Out-of-state tuition is approximately twice the in-state tuition.

Wisconsin Indianhead Technical Institute
Rice Lake Campus
1900 College Drive
Rice Lake, WI 54868
715-234-7082

WITI offers a 9 month CATV technical program including CATV electrical principles, field techniques, mapping, and mathematics. Tuition is $21.75 per credit hour or approximately $1200 for the complete program.

A TRIAL OF A NATIONAL PAY-PER-VIEW ORDERING AND BILLING SYSTEM

Andrew F. Bulfer, AT&T Communications
Matthew D. Miller, Viacom International
Nancy Frank, CableData

ABSTRACT

A new concept in fully automated pay-per-view ordering and billing is presented. The system has the potential for nationwide scope, very high impulse capacity, and easy implementation by the cable operator. It would be simple and easy for the cable subscriber to use and would have low initial cost. It features a direct interface with the cable company's billing system so that all the elements of the pay-per-view transaction are handled in a fully integrated manner. A trial is planned in Milwaukee, Wisconsin starting in June, 1986.

INTRODUCTION

On December 5, 1985, AT&T, Showtime/The Movie Channel, Viacom Cable, and CableData announced they will participate jointly in a concept trial of an automated impulse pay-per-view ordering service that will allow cable television customers to order premium pay-per-view programming on a nationwide basis. The nine month trial is scheduled to begin in June, 1986 at a Viacom cable system in Milwaukee, Wisconsin.

There are four elements which must be performed in a successful impulse pay-per-view transaction:

1. Order Entry;
2. Event Scheduling (converter authorization/de-authorization);
3. Program Delivery;
4. Billing.

Because order entry is such an obvious problem, much attention has been focused on it, perhaps distracting attention from the other elements of the pay-per-view transaction. It is the goal of the Milwaukee trial to demonstrate a ***system*** in which all of the elements are handled in an integrated, fully-automated fashion and which is capable of accommodating a heavy volume of impulse orders. The system has the potential to be nationwide in scope, easily implemented by the cable operator, and cost-effective.

The order entry technology will be furnished by AT&T and will be based on an integration of three elements: AT&T 800 Service which allows consumers to place toll-free orders; mass announcement systems installed within the AT&T public switched network to enable quick verbal acknowledgement with very high capacity; and Automatic Number Identification (ANI) which captures the caller's telephone number and passes it to the order processing system. The order processing system will be provided by CableData and will feature an automated interface between the ANI data stream from the AT&T network and the CableData business system as well as an event scheduling and billing package. Viewer's Choice, Showtime's pay-per-view programming service, will provide programming via an encrypted national satellite feed. The combination of these components will form a complete end-to-end pay-per-view system.

This paper presents details of the Milwaukee trial, including a description of the entire transaction flow starting with the cable subscriber's telephone call and concluding with the receipt of an accurate, auditable bill.

WHY A NATIONAL SERVICE?

The Milwaukee trial will test a system concept with national scope. Specifically, the AT&T order entry technology is based on the nationwide AT&T public switched network which can be accessed from any telephone in the country including both rotary and Touchtone telephones. The ANI information is delivered to the cable company using standard communications protocols, and the programming is delivered by a national satellite feed. Why have the trial participants chosen this approach?

The authors believe strongly in the merits of a readily implemented, cost-effective, turnkey ordering system with national scope and very simple customer interface. Such a system could be sponsored by a national pay-per-view distributor such as Viewer's Choice and would have advantages of scale which can minimize the economic and operational hardship inflicted on any individual cable system that wishes to offer its subsribers pay-per-view programming. This arrangement would encourage the growth of the entire pay-per-view industry and benefit all industry participants including studios, programmers, cable operators, and vendors to the cable industry.

A national order entry system would help to build the pay-per-view audience more rapidly by making ordering simple, uniform, and widely understood by consumers. Furthermore, such a system would make it possible to utilize nationwide marketing techniques, which have lower costs per thousand and can be more directly integrated with the programming, but which are not useful when potential audiences are small. A standardized interface to the cable operator's business system would greatly reduce software development time and expense. In addition, since many business management systems already interface with the addressable controller, the time, cost, and difficulty of event scheduling should be reduced.

Many of these benefits would flow directly to the operator as reduced cost and difficulty. Others, like marketing efficiency and greater customer understanding and ease of use, should result in revenue increases from higher buying rates.

A streamlined national transaction management system would offer benefits not only to industry participants but also, equally importantly, to subscribers. Reduced cost and simplified ordering could support a healthy industry, capable of providing a diversity of pay-per-view programming in a cost-effective way to a substantial audience.

REQUIEMENTS OF A NATIONAL ORDERING SYSTEM

In the authors' view, a national pay-per-view order entry system must satisfy five general requirements:

1. Very High Impulse Capacity;
2. Simple And Easy To Use;
3. Economical With Low Initial Cost;
4. Direct Interface With The Cable Company's Billing Computer;
5. Turnkey The Cable Operator.

The rationale for these requirements is described below.

High Impulse Capacity. Market research has consistently shown and experience has proven that consumers wish to wait to order until the last moment before a show and will do so if left on their own. Indeed, for marketing reasons, this behavior is to be encouraged in order to benefit from impulsive consumer buying decisions. However, impulse buying makes extraordinary demands on the order entry system. A good system must have sufficient capacity to handle the traffic when all the orders for a routine movie arrive within the last few minutes before the movie begins.

Simple And Easy To Use. The consumer interface must be extremely simple, easy to understand, and natural to use. This, again, will allow consumers to make last minute buying decisions and then implement their decision without being inhibited, intimidated, or foiled by the ordering system.

Economical With Low Initial Costs. That the system must be economical should go without saying in a relatively low margin business such as pay-per-view. Moreover, a system with low initial cost will allow operators to experiment with pay-per-view with minimal risk.

Direct Interface With The Cable Company's Billing Computer. This is a requirement of an overall pay-per-view transaction processing system that is all too often ignored. In addition to enabling fully automated handling of pay-per-view transactions from beginning to end, it will allow sophisticated on-line error and validity checking that will maximize security and minimize customer service problems.

Turnkey To The Cable Operator. A standard overall system that can be simply installed and operated by the cable operator is extremely important. Not only will it encourage more rapid adoption of pay-per-view throughout the cable industry, it will also gain advantages of scale by allowing hardware and software development to be done once nationwide with concomitant cost economies.

CONCEPTUAL OUTLINE OF A NATIONAL ORDERING SYSTEM

Based on the above requirements, a national ordering system could take the following form:

1. The ordering system would be built around AT&T Advanced 800 Service. Each movie or event that may be ordered would be assigned a unique toll-free 800 number. To order, the customer would dial this number.

2. An automated acknowledging announcement would be given by a mass announcement node inside the AT&T public switched network so that massive impulse capacity could be available. No 800 service lines to the sponsor's premises — which have led to traffic choking and limited capacity in the past — would be required.

3. ANI would be delivered to a national pay-per-view distributor such as Viewer's Choice. Economic distribution of the ANI information to the cable operator could be handled via a data subchannel on the satellite feed.

4. Fully automatic processing, validation of the order, and activation of the addressable system could be achieved by interfacing the ANI data stream from the satellite receiver directly to the cable company's billing processor.

The start-up costs for a cable operator to offer pay-per-view with such a system would be minimal. There would be no capital or installation expense in the subscriber's home since the system would be implemented with hardware already there: the addressable converter for program reception and the telephone for order entry.

THE MILWAUKEE TRIAL

In an attempt to determine the value and operational characteristics of a national system, AT&T, Viacom, and Showtime/The Movie Channel, have entered into an agreement to do a small scale trial of such a system. In the trial, Showtime will provide the pay-per-view product via its Viewer's Choice service, Viacom will furnish the trial cable system, and AT&T will assemble a small scale, localized version of a national ordering system. In the trial, CableData has agreed to provide the processing of the ANI, the interface with the billing system, and the activation of the addressable system.

Trial Location

The trial will take place at Viacom Cablevision Of Milwaukee, a 36,000 subscriber Viacom system serving fourteen suburban communities in the Milwaukee area. The system has 108 channels of which over 60 are currently activated. Every subscriber has an addressable converter and will have access to the pay-per-view service in the trial. The system uses Zenith Z-TAC one-way addressable equipment.

This site was chosen for a number of reasons including: the demographics of its subscribers are typical of cable subscribers nationwide, every basic subscriber has an addressable converter, the system is of manageable size, it is served by CableData's billing system, every local telephone company central office will be capable of transferring ANI by the time of the trial, and AT&T will have the necessary network features installed in its Waukeesha, Wisconsin No. 4 ESS toll switching office, which serves the Milwaukee area.

Trial Objectives

The objectives of the trial are to gather information on the value and performance of this type of fully automated, potentially nationwide, ordering/billing system in a live pay-per-view environment and to identify issues associated with its use. There are five categories of information desired:

Consumer Reactions. This includes finding out how consumers like ordering pay-per-view movies and events using the system, whether they can use it effectively, the type and quantity of errors they make, the type and quantity of customer service problems that result, and whether changes in the system are required to ameliorate the effects of these errors.

Marketing Issues. These include determining the type of consumer education required, if any, a quantification of the frequency of use, and an evaluation of the marketing value of the system.

Technical Problems. These include identification and solution of any unexpected interface problems and the quantification of error rates, speed, time delays, and other measures of overall performance of the entire system and its components under conditions of real consumer usage.

Operations Problems. These include problems that may occur in operating the ordering system from both a cable company, service sponsor, billing vendor and AT&T perspective.

Billing Issues. One of the important objectives of the trial is to identify problems and issues associated with the automated interface to the billing system and, more generally, with the process of billing and collection for pay-per-view movies and events.

Trial Schedule

The trial is scheduled to commence in June, 1986 and to terminate in March, 1987, nine months later. Since the trial is primarily a marketing trial, it must run long enough for consumers to learn to use it and become comfortable with it — hence nine months. The start date was determined by technical hardware and software availability within the AT&T network.

Trial Architecture

The trial architecture is shown in Figure 1. The Viewer's Choice pay-per-view programming feed originates at the Showtime satellite uplink facility in Hauppauge, Long Island, and is beamed to the trial site via Transponder T5 on Satcom 3R. Customer's telephone orders will be handled within the AT&T public switched network using a modified version of 800 Service. The calling telephone numbers will be passed to Viacom's CableData Tandem computer system in Cleveland which will perform a number of validity checks, identify the callers that ordered, and transmit the appropriate data back to the addressable system controller in Milwaukee to enable descrambling in the customers' addressable converters.

Trial Order Entry

A description of the order entry process for the trial is as follows:

1. Each pay-per-view channel available will have a toll-free 800 area code telephone number associated with it. Current plans envision two such channels with the two numbers: 1-800-VIEWER1 and 1-800-VIEWER2. To order a pay-per-view movie or event, the cable subscriber simply dials the ordering telephone number for that channel. The caller may utilize a telephone with either Touchtone or dial-pulse signaling. However, the consumer must dial from his or her own home or from a telephone known to the local cable company.

2. The call is routed, as are all 800 calls, by the local telephone company to AT&T's network. AT&T obtains the caller's telephone number automatically by Automatic Number Identification from the local telephone company's central office under the terms of equal access.

3. The call is routed to AT&T's Cleveland switching office where, by an arrangement of trunks within the switching equipment, it terminates at an existing AT&T mass announcement facility. Here, answer supervision is returned, and a "thank you" announcement is given to the caller acknowledging that the order has been placed. When the caller hears the announcement, he or she either hangs up or the announcement facility disconnects the call when the announcement is completed.

4. AT&T passes the calling and called number (indicating the channel which carries the movie or event that the customer wants) to the CableData computer in Cleveland over a dedicated private data line in a standard data protocol.

5. The CableData computer, a Tandem Non-Stop system, contains an on-line database of the cable company's subscribers' telephone numbers. The processor performs a number of validity checks or "edits" including:

- That the customer's telephone number exists in the database;
- That the customer's home is equipped with addressable outlets capable of handling pay-per-view;
- That the customer's account is active;
- That the customer is not in collections;
- Whether ordering the event will not put the customer beyond their credit limit;
- Which outlet in the home to authorize.

Those orders not qualifying for pay-per-view service will be noted automatically by CableData's DDP software. A phone call to that customer, informing them that their order cannot be accepted, can be placed either automatically by DDP software through the Tandem computer and Programmable Auto Dialer (PAD), or manually by customer service representatives using a report generated by DDP. The cable company may choose to pursue these as future customers, candidates for addressable converter installation, or to motivate payment of an overdue bill.

7. The Tandem processor in Cleveland then passes the consumer's identity to the addressable system controller in Milwaukee through an automated interface via a network of private data lines. At or before the start of the program, descrambling is activated in the subscriber's addressable converter.

8. Counts of the number of orders for each program will be available to the pay-per-view program distributor and other authorized recipients within minutes of their being placed.

9. The charges for the pay-per-view program will appear on the cable subscriber's monthly cable bill prepared and rendered by CableData.

Trial Capacity

The capacity of the trial system has been designed to be able to handle any impulse load that can reasonably be expected. Since the system is composed of a sequence of processing steps, the ultimate capacity will be determined by the capacity of the slowest component. An analysis of the capacity of each step is as follows:

AT&T Public Switched Network Capacity. The AT&T network will be configured to handle up to several hundred calls per minute in the trial depending on the call holding time. This is determined by the trunking arrangement in the Cleveland switching office. The local telephone company central offices, the AT&T switching offices involved in the calls, and the mass announcement system have far greater capacity and so are not expected to be a limitation. Since the calls themselves have no egress from the AT&T network, no 800 service lines to the sponsor's premises, which have traditionally been the bottleneck in telephone-based systems, will be required.

CableData Capacity. CableData's DDP information and billing system, using a Tandem Non-Stop computer, will provide rapid processing of: 1) all calls received from AT&T, and 2) commands sent to the addressable controller authorizing those converters qualifying for the pay-per-view service ordered. This is accomplished by prioritizing both the verification edits and box authorization commands occurring between memory and disk, maximizing the hardware capabilities of the Tandem through use of CableData's DDP software. The exact capacity of this configuration will be determined by benchmark tests prior to the trial. However, it is expected to be more than sufficient to process the anticipated traffic.

Addressable System Capacity. The current Zenith system installed in Milwaukee uses a Zenith-provided Intel addressing processor whose capacity is 1200 to 1800 calls per hour. This is expected to be the limiting system factor. Viacom is considering replacing this processor with an HP1000 minicomputer whose capacity will far exceed that of the Intel processor.

The system is designed to be graceful under overload, should it occur. If calls arrive at such a high rate that the trunks in the Cleveland switching office are overloaded, callers will hear a standard reorder tone ("fast busy"). The other system components are all designed to buffer information that cannot be immediately processed so that, under overload conditions, orders are simply delayed, not lost.

CONCLUSIONS

The nationwide service concept described above is in the study stage and has not been committed for nationwide deployment. But, if the trial results are positive and it is determined that a service offering of this type would be useful and valuable, then it is likely that a nationwide service would be offered.

If it were to be deployed, the AT&T portion would be available under tariff or other appropriate regulatory structure to anyone. It is likely that it would be purchased by national pay-per-view distributors such as Viewer's Choice who would offer the service to its own affiliates. Likewise, CableData, as a supplier to the cable industry, expects to make any software or hardware developed as a result of the trial available to all of its customers.

The pay-per-view transaction system described in this paper has the potential to satisfy the most important requirements of ordering and billing:

- Nationwide Scope;
- Very High Capacity;
- Ease And Simplicity To Ensure Customer Acceptance;
- Low Up-Front Costs;
- Full Automation Including Billing;
- Turnkey Installation And Operation.

The partners in the trial, AT&T, Showtime, and Viacom, together with CableData believe that they have an important concept for the fundamental health and growth of the pay-per-view industry.

Figure 1 on followng page

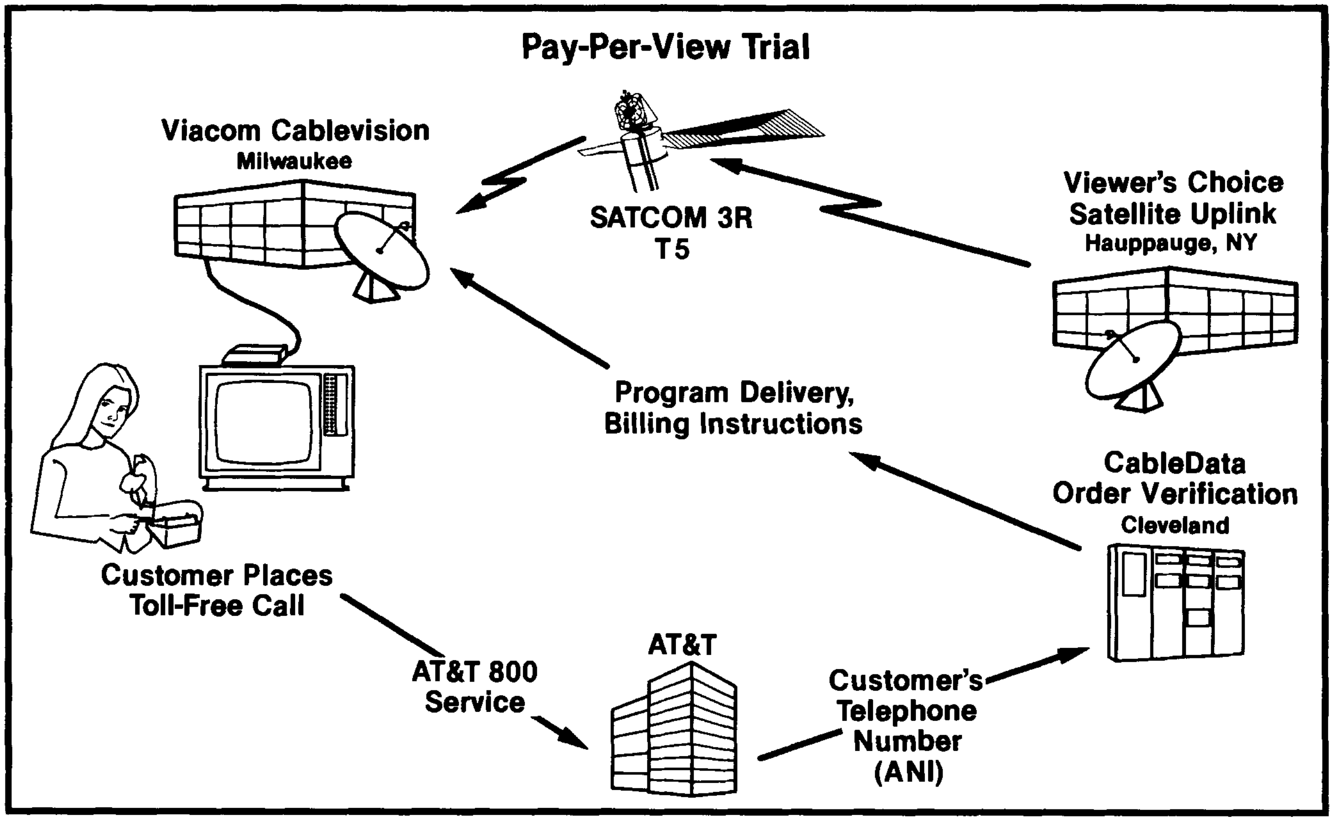


Figure 1 — Trial Architecture

AIRSPACE MEASUREMENT OF CATV SYSTEM CLI

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ABSTRACT

This paper discusses the signal leakage measurements made in the airspace above Dallas and Fort Worth, Texas to determine cable system Cumulative Leakage Index (CLI).

Discussed is the monitoring equipment used, the pre-flight and in-flight calibration tests, and the outfitting of the aircraft used in the flyover.

Cable systems with shielded and unshielded cable fittings, as well as new (quad shield) and old (60% braid), were included in the measurements. The systems with the best procedure to prevent leakage also had the most aggressive monitoring program and, as expected, had little problem complying. The systems with fewer precautions to prevent leakage had a more casual monitoring program and, judging by ground measurements, had more severe leaks.

The measurements were made at an altitude of 450 meters (1,476 feet) above average terrain and at Channel C carrier frequency. The purpose was to determine the compliance with anticipated FCC requirements for 10 uv/meter maximum leakage.

The first test (April, 1985) indicated that the best system had 2 uv/meter in the airspace, an intermediate system, --- i.e., shielded cable fittings, a monitoring program, but with some old house drops --- had approximately 4 to 8 uv/meter and a worst case system had higher than 20 uv/meter.

The test in December showed house wiring to be less of a factor than originally thought, with 3 uv/meter being a typical value for a good system, even those with some older drops.

It is concluded that a system with shielded fittings and an aggressive ground leakage monitoring program would easily comply with the future FCC requirements of 10 uv/meter at 450 meters above the cable system being tested.

INTRODUCTION

The use of aeronautical frequencies 105-136 MHz and 225-400 MHz by cable TV systems has always been carefully controlled by the FCC to avoid interference to aeronautical communication and navigation systems.

In locations where cable systems have been allowed to operate in these frequency bands prior FCC notification has always been required. Reduced power and offsets from standard channel frequencies have historically been used to avoid conflict with other services.

In the Opinion and Order 21006, the FCC authorizes the use of aeronautical frequencies without prior notification provided specified offsets are maintained and a ground-based leakage monitoring program is implemented. After July 1, 1990 systems will also have to show compliance with certain leakage criteria, either the ground-based CLI (Cumulative Leakage Index) or the maximum of 10 uv/meter in the airspace. Ground-based CLI measurements have been discussed in the literature; until the FCC Docket 21006 was published no limit of airspace leakage was widely circulated. This docket specifies a limit of 10 uv/meter field strength in the airspace 450 meters above the cable TV system.

When it was first believed that CLI measurements would be required for signal carriage, ground-based measurements were attempted by Sammons. Initial tests showed that the time required to cover 75% of the Metropolitan Fort Worth area could be as high as three man-months, especially if the levels measured in the street were converted to equivalent levels 3 meters from a possible source. In addition, the uncertainty in estimating distances between antenna and sources is high. Finally, ambiguous results can easily be obtained in locations where more than one high level leak may exist. For these reasons, it was decided that a flyover would provide the most definitive measurement of system airspace leakage.

Two tests were taken: one in April of 1985, covering Sammons' Fort Worth system and some just-acquired adjacent systems. The second test in December of 1985 covered the same areas plus those of a second acquisition. Overall, a good sampling of systems was measured: with and without cored cable fittings, with and without multiple shielded house drops, and with a variety of leakage monitoring programs.

EQUIPMENT AND CALIBRATION

Receiver

The receiver used was a Singer NM-37/57 (in the first test) and a Polarad ESV (in the second). The receiver criteria was:

Sensitivity: -108 dBm

Bandwidth: 25 KHz maximum

Calibrated output to drive Y-T chart recorder

Frequency Resolution: ± 1 KHz

Provision for internal battery or 12v operation

The receiver sensitivity was determined by the expected signal: 10 uv/meter will theoretically produce -98 dBm in a half-wave dipole antenna, and a minimum receiver sensitivity of -108 dBm would then provide a 10 dB margin. The receivers used actually had about -117 dBm maximum sensitivity, so the minimum detectable field strength was about 1 microvolt/meter.

Both also had proper output to drive an Y-T recorder and the required powering provision. The Polarad had a synthesized local oscillator which displayed frequency directly in 1 KHz increments; the Singer did not, but the local oscillator frequency was available at a test port so an external counter was used to accurately determine input frequency. Both were heavy - the Singer weighed 65 pounds with batteries. A separate input filter was found necessary to reduce interference generated from out-of-band signals.

To calibrate the measurement system, the FCC requires that a known 10 uv/meter field be established at the test altitude of 450 meters. This field is generated by an antenna and signal generator on the ground.

The FCC is specific about the calibration antenna. It is to be "... a well characterized antenna consisting of orthogonal resonant dipoles, both parallel to and one quarter wavelength above a ground plane of a diameter of 2 meters or more at ground level. The dipoles shall have centers co-located and be excited 90 degrees apart." [1]

This antenna produces circularly polarized signals. The antenna used in these tests was cut for Channel C (132 MHz) and required +15 dBmv excitation to generate 10 uv/meter 450 meters away. It should be noted that ground-based tests to verify proper operation are difficult to perform; the ground, and any structures, distort the generated field. It is best, if one chooses to verify operation before a flight, to use adjacent hills and raise the transmit and receive antenna as high off the ground as possible.

In contrast to the difficulty in obtaining good gound-based readings, the initial flyover of the calibration antenna produced results within 3 dB of calculated values. Since the aircraft fuselage was close enough to have a definite effect on the antenna response, this was considered a comfortably close correlation. We found it necessary to fly directly over the antenna to get the most consistent results.

Receiving Antennas

Two dipole receiving antennas were used on the aircraft; they were tied between the tail and the wing tie-down points on each side of the fuselage. The outputs were combined before entering the receiver. With two antennas it is believed at least one would pick up a signal should the aircraft fuselage shield the other. This advantage of wider coverage should outweigh any problems caused by 180° phase cancellation that would occur in some situations. The antenna array gave consistent results during the in-flight calibration, even though its field was probably distorted because of its proximity (two to three feet) to the metal fuselage. It is important that the pertinent channel frequencies be measured just before testing; a slight drift can place the signal out of the receiver's bandwidth.

TIME REQUIREMENTS

Preparation and Test

Approximately one man-month was required before the initial tests were taken; this time was used for equipment selection, calibration and receiving antenna design and construction, ground tests, and outfitting the aircraft. Only about one day of preparation was required before the second test. The plane flew at an airspeed of 75 to 90 knots (approximately 100 mph). The flying was done in one-mile grids; it took about one day to cover the entire Tarrant County area. Additional close systems could have been covered, if desired. An additional day was used to cover systems that were 30 to 40 miles away.

A street map was marked to guide the navigator when flying over the Fort Worth area. Visual estimations were used when flying over smaller towns (like Weatherford) where three or four passes were adequate.

TEST RESULTS

System	Date	Leakage uv/m	Monitoring Program	Shielded Cable Fittings	All Quad or Triple Drops
Benbrook	4-85	10 *	Yes	Yes	Yes
	12-85	3	Yes	Yes	Yes
Burleson	4-85	30	No	No	No
	12-85	3.2	Yes	Yes	No
Crowley	4-85	10	No	No	No
	12-85	3	Yes	No	No
Fort Worth	4-85	3	Yes	Yes	Yes
	12-85	22.3 **	Yes	Yes	Yes
Richland Hills	4-85	10	No	No	No
	12-85	3	Yes	Yes	No
Saginaw	4-85	14	No	No	No
	12-85	2.5	Yes	No	No
Watauga	4-85	8	No	No	No
	12-85	3	Yes	Yes	No
Weatherford	4-85	10	No	No	No
	12-85	3	Yes	Yes	No
White Settlement	4-85	4	Yes	Yes	No
	12-85	4	Yes	Yes	No

* Caused by one leak
** Two locations greater than 10 uv/meter

When the first test was taken, the data indicated a measurable difference between systems with some lower quality drop and house wiring (60% braid) and those with only high quality wiring (triple or quad shield). The December measurements indicate that the quality of house wiring may have less effect than originally thought. It is unlikely that lower quality house wiring will cause 10 uv/meter signals in the airspace; it can, of course, create other problems such as interference to amateur radio services and can allow devastating ingress to midband channels.

Although the airspace measurement is not designed to locate individual leaks, it did, on one occasion during the April test, indicate an unusually high level (10 uv/meter) in the Benbrook system. Ground tests in the area located a radial feeder crack.

The December test showed four locations of high leakage in Fort Worth, two higher than 10 uv/meter. A ground check of the area is occurring, but results are not available in time for inclusion in this paper. They will be presented at the technical session.

One question has been raised by the Fort Worth data: If, in an otherwise tight system, some isolated severe leaks are measured by the flyover, and if ground-based measurements are used to locate and correct the leak, can the improvement in airspace leakage be demonstrated without an additional flyover? Can we be sure that all the contributing leaks are found?

Not, of course, with absolute certainty, but a conscientious monitoring program of the affected area should provide reasonable assurance that the system is clean.

CONCLUSIONS

The following conclusions can be reached from the test data:

1. Average signal levels of 2 to 4 uv/meter will be measured from well maintained systems.

2. A routine leakage monitoring program is essential for maintaining this level.

3. Shielded cable fittings are helpful but not quite as necessary as a routine monitoring program.

4. Drops and house wiring quality are not critical for maintaining the leakage level of 10 uv/meter @ 450 meters.

5. A system with inadequate leakage monitoring programs will probably exceed 10 uv/meter @ 450 meters.

ACKNOWLEDGEMENTS

Special thanks are given to:

(1) Chet Swafford, our navigator, who first suggested that the flyover might be cost-effective.

(2) Herb Timberlake, Sammons' senior engineer, whose technical advice and hands-on support was a significant part of the program.

REFERENCES

1. FCC Docket 21006
§ 76.611 (a) (2)

ALTERNATIVE PAY-PER-VIEW TECHNOLOGIES: A LOAD CAPACITY ANALYSIS

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ABSTRACT

1986 has been heralded as the year that will establish pay-per-view as a significant revenue-producing business for the cable industry. The advent of satellite delivered programming in PPV format, along with the ever-expanding universe of addressable converters, have motivated many cable system operators to analyze the viability of the pay-per-view business in their own systems.

Two essential elements must be examined in such analysis:

1. The anticipated volume of PPV program sales.
2. The capacity of the ordering mechanism which enables the subscriber to purchase a film or event.

This paper will present the penetration levels and peak ordering load distribution data from cable operators with extensive pay-per-view experience, and will evaluate the various ordering mechanisms currently available or in development. In the contexts of system size, PPV buy rates, and peak load - handling requirements, examination of each technology's capacities and limitations will be provided to assist the cable operator in selecting the ordering mechanism most appropriate for his/her own application.

OPERATOR EXPERIENCE

Penetration levels of pay-per-view programming vary widely among systems, as indicated by research of the operators whose data were used in compiling this paper: Cox Cable/San Diego, Daniels/ Baton Rouge, Gill Cable/San Jose, Group W Cable/Roseville, NYT Cable/NJ, Oceanic Cable/Honolulu, Rogers Cable/Portland, Storer Cable/Beaverton, Tribune-United/ Oakland, and Warner Amex/Columbus.

Naturally, each system offered programs with varying frequency, sales promotions, pricing, regional interest, (e.g., sporting events), and "early order" incentives.

Many variables affect the but rates of a PPV program, and no attempt is made here to downplay their importance; however, since variables such as program content, market demographics and frequency/positioning of showings do not substantially impact the distribution of peak order load, only those factors pertaining to the ordering mechanism technology will be isolated for discussion.

Crucial to the comparison of PPV ordering mechanisms is the maximum load of purchase tranactions that must be accommodated in order to optimise the sales potential of the program being offered. Additionally, the buyers' behavior should be considered, to predict the traffic patterns in event orders that will define the system's peak load.

Figure (1) tabulates the average monthly (cumulative) penetration levels of pay-per-view programs to addressable subscribers experienced by several systems.

FIGURE #1

SYSTEM	% PEN./MO.	ADDR. SUBS	NET PEN./MO.
NYT Cable†	70%	21,000	14,700 orders
WAX/Cols.†	54%	29,000	15,660 orders
Rogers/Port.††	27%	70,000	18,900 orders
Trib./Un.††	25%	4,800*	1,200 orders
Daniels/B.R.†††	20%	30,000	6,000 orders
Gill/SanJ.†††	7.5%	35,000	2,625 orders
GWC/Rosv.†††	2.5%	14,000	350 orders
Cox/SanD.††††	8.5%	120,000	10,200 orders
Oceanic††††	11%	88,000	9,680 orders
Storer/Or.††††	10%	33,000	3,300 orders

† fully interactive two-way addressable system
†† at least 1/2 of addressable subs are two-way, balance call-in to CSR's
††† subscriber call-in to CSR's
†††† subscriber call-in to automated voice-response system
*actual addressable subscriber base in this system is 50,000, but pay-per-view was offered to a control group of 4,800

Several observations can be made in a cursory examination of the table in Figure (1):

1. The volume of PPV orders processed is impacted as much by the size of the subscriber base as by the percentage of those subscribers who buy an event. Three systems had subscriber bases of 29-33,000, with penetration rates varying from 10% to 54%. The total volume of orders processed for these systems ranged from 3,300 to 15,660. As mentioned earlier, many variables can affect the penetration rates of PPV programming; the important point here is to identify which technologies will be most appropriate for the volume of orders anticipated in a particular system.

2. It is also interesting to note that the systems with the highest monthly penetration rates, 25% and above, offer true "impulse" pay-per-view to at least a portion of their subscriber bases, with interactive addressable systems. This correlation is also evident in research conducted by United, Rogers, and Group W. Each MSO found that in systems offering PPV by both subscriber call-in and impulse ordering technology, the impulse-buy orders outnumbered the call-in orders by two to one (in several cases, the ratio was 3:1).

3. Several of the systems listed in Figure (1) are currently operating with limited addressable dedication. The penetration rates observed here must therefore be extrapolated to the ultimate addressable subscriber base, to determine whether the existing ordering mechanism will handle the anticipated volume.

The most important factor in identifying peak system loads, however, is the maximum order volume to be handled at any given point in time. The penetration rates experienced for single showings of successful recent PPV programs/events are outlined in Figure (2), along with an extrapolation of these rates over each system's extended addressable base.

Figure 2
PPV EVENT PENETRATIONS

	Current Addr. Subs	Pen/Event	Orders/ Event	Ultimate Addr Subs	Ult. Orders/ Event
NYT	21,000	4.1%	861	120,000	4,920
WAX/CMS	29,000	5.6%	1,624	53,500	2,996
Daniels/BR	30,000	50%	15,000	30,000	15,000
Cox/SanD	90,000	6%	5,400	260,000	15,600
Oceanic	88,000	4%	3,520	155,000	6,200
GW/Rosev	14,000	3%	420	14,000	420
Gill/SanJ	35,000	15%	5,250	150,000	22,500
Trib/Un	2,400	5%	120	55,000	2,750

Note that the average buy rate for a single event is between 4 and 6%. For Oceanic Cable in Honolulu, a 4% take rate out of 88,000 subscribers yielded a respectable 3,520 orders. If the same penetration rate is anticipated for the system's extended subscriber base of 155,000, the PPV ordering mechanism must be capable of handling 6,200 purchases. But how many of these orders come in at any given point in time, and more importantly, what is the peak load the system must accommodate to assure that the subscribers who want to purchase the program have access to it?

For a true picture of the event ordering traffic each system must contend with, it becomes necessary to examine peak load distribution prior to the event's start time (Figure 3), and to apply the peak load to the anticipated optimal penetration level for the system.

In those systems with impulse capability, and hence, no practical limitation on last minute orders, operator consensus was that 50% of the event orders came in at the last 15-20 minutes prior to start time (remember, this group also reported double the buy rates).

The systems with subscriber call-in ordering procedures, by design and by subscriber education, had as few as 15% of orders in the last 15-20 minutes, with 50% of the orders coming in before the two hours preceding the event. As a group, however, these systems had little or no data on order distribution, and several suspected they were losing last minute "impulse buyers" to busy signals (Rogers has estimated this loss to be as high as 20% for a popular movie). All believed that their buy rates would be enhanced by a technology that would facilitate impulse purchasing.

For purposes of analysis, it is

conservative to assume a 50% peak penetration rate distributed (variably) over the last 30 minutes prior to event start.

If we go back to Figure (2) and factor in the distribution peak of 50% to the total orders for a single event, the total orders to be handled in the last 30 minutes prior to event start can be derived. These net, peak period orders are presented, both for current subscriber bases and for expanded systems, in Figure (4).

Figure #4

PPV PENETRATIONS

	CURRENT ADDR SUBS	PEN/EVENT	ORDERS/ EVENT	ULTIMATE ADDR SUBS	ULT ORDERS/ EVENT	CURRENT PK @ 50%	ULT. PEAK @ 50%
NYT	21000	4.10%	861	120000	4920	430.5	2460
WAX/CMN	29000	5.60%	1624	53500	2996	812	1498
DANIELS/BR	30000	50.00%	15000	SAME	15000	7500	7500
COX/SAN D	90000	6.00%	5400	260000	15600	2700	7800
OCEANIC	88000	4.00%	3520	155000	6200	1760	3100
SW/ROSEV	14000	3.00%	420	SAME	420	210	210
GILL/SAN J	35000	15.00%	5250	150000	22500	2625	11250
TRIB/UN. MI	2400	5.00%	120	55000	2750	60	1375

The system with the most orders coming in over their expanded addressable base is Gill Cable, with 22,500 orders, at 15% penetration of 150,000 subscribers. At Gill's present subscriber base of 35,000, or more manageable volume of 5,250 orders comes in for the successful single event. But in either case, a bottleneck may occur if 50% of these orders are received in a 30-minute period (we'll return to this point).

Naturally, there are marketing solutions to any such situation; subscribers can be "trained" to pre-order; the event (if not a live sporting event) can be offered several times throughout the month to distribute the ordering load more evenly; pricing can be adjusted to reduce the number of orders. All these measures, and others, have been utilized in the system that have shown the most success in pay-per-view without ordering mechanisms that allow for substantial peak load-handling capability (see Figure [1]). But the same system operators also agree that by offering their subscribers true impulse purchase capability, they could sell more PPV programs.

Figure #3

(see CONCLUSION)

The dilemma of optimizing PPV sales without encumbrance to the system must be addressed through technology. An analysis of several PPV ordering mechanisms follows, with emphasis on application to our sample systems' peak ordering load requirements.

PPV Ordering Mechanisms

There are two broad categories into which every PPV ordering mechanism can be placed: real time, vs non-real time.

Real Time systems require communication between the subscriber and the headend or the business office at the time the order is placed --- whether through a telephone call to aCSR, or by selecting the program directly through the interactive addressable converter. Decoder authorization procedures, such as account verification and credit check, account number to terminal ID match, and validation of the transaction, are performed at the time the order is received, and the transaction is completed with an authorize command to the addressable decoder. Real time ordering systems include CSR call-in, automated voice responce call-in, ANI (automated number identification), some telephone dialer systems, and two-way interactive addressable converters.

Non-real time systems do not require that the subscriber and the headend or business office ever communicate at a given point in time. The subscriber's addressable decoder can be pre-authorized for a down-loadable credit limit, enabling the subscriber to select an event locally, without further communication with the cable system. The subscriber's selection is stored in the converter, and the headend later retrieves the ordering information by commanding the terminal to report its memory contents. The return path for terminal reporting can be either telephone or two-way cable, but the distinguishing characteristic here is that the communication loop need not be completed at the time the event is ordered. This technique is commonly known as "store and forward" technology.

CSR Call-In

Although several operators have initiated very successful PPV programs utilizing CSR's to accept telepone calls and mail-in pre-orders, the inherent limitations in system capacity must curtail last-minute impulse purchases.

Peak load capacity is determined in these systems strictly by the number of telephone lines coming into the cable system's office. Gill Cable, with 16 lines dedicated to CSR's, can handle about 16 orders per minute at 60 seconds/ transaction. This translates to 480 calls in any half hour peak period prior to event start, 9% of the 5,250 orders received on an event with 15% penetration of Gill's 35,000 subscriber base.

If the transaction time can be reduced to 30 sec./call (rather difficult, since credit checks must also be done simultaneously with multiple users on the system), 960 orders can be processed in 30 minutes, a maximum of 18% of Gill's orders for the same event.

This ordering mechanism has served many operators well in their initial forays into pay-per-view, and subscribers have adapted some of their buying habits to the system's capacity. But maximization of the PPV business in a particular cable system requires that any subscriber who wishes to purchase an event may do so. In order to accommodate the "impulse buyers" who purchase in the last 30 to 60 minutes, and to ensure that would-be buyers do not reach a busy signal or an on-hold queue, a different technology must be employed.

Automated Voice-Response

An automated voice-response system is the next step up in technology. The maximum load capacity is still determined by the number of telephone lines dedicated to order-taking and by the time required to process a transaction, but the the number of CSR's required is reduced.

The subscriber still makes a telephone call to order a program/event, but rather than talking to a CSR, responds to prompts from a digitized voice by punching the appropriate buttons on a touch-tone phone. Subscribers without push-button phones (50% of the telephone population, approx. 30% of cable households) stay on the line for a live CSR to complete the transaction, unless provided with a tone-generating device.

The touch-tone subscriber's order, when completed, is handed over from the voice response computer to the billing computer for credit check and telephone/ account number to terminal ID match, and then down-loaded to the addressable controller for the decoder authorization poll. (Some voice response systems vary slightly in how these steps are handled; some voice response computers have mini data bases that are updated daily with credit clearance, and terminal ID match to telephone/account numbers to speed up the validation process. Others also tie into dial-out systems which initiate return calls to the subscriber whose account is not current, or whose transaction was invalid.)

Peak load capacity is still only 1,920 orders per hour for a 16-line system with 30-second transactions. Referring back to Figure (4), this capacity for 960 calls in the last 30 minutes would accommodate only 4 of the 8 operators listed if 50% of their orders came in the last 1/2 hour.

Although voice response systems are very effective for cable operators with prolonged event-order distribution, their reliance on real-time telephone communiation with subscribers still inhibits the impulse buyer who wants to place an order in the last 30-60 minutes.

Auto-Dialer Ordering Devices

Several manufacturers have conducted field tests of auto-dialer devices which further stream-line the ordering process for the subscriber. The dialer ordering unit is allocated an ID or "address" by the cable operator, and connected to the subscriber's telephone. When a subscriber wishes to order a program or event, the appropriate keys are depressed on the dialer device in the home. The auto-dialer calls its own control computer at the cable office and relays the event ordering information, which, along with the dialer's ID, is then processed for account verification and credit check. If all is well with the order, the information is passed along through the billing system and the addressable controller for converter/ decoder authorization. The subscriber's feedback on transaction acceptance is through LED's on the dialer device.

The auto-dialer cuts down substantially on the transaction time per order (approx. 10 seconds), enabling a 16-phone line cable system to accept 2,880 orders in 30 minutes. This capacity would enable Gill Cable to process 55% of their 5,250 orders in a one-half hour peak period, which should adequately facilitate the last-minute purchases experienced by the impulse-capable operators discussed previously.

Even with this increased order-taking capability, however, the auto-dialer system is subject to an additional bottleneck that is faced by all real-time based ordering systems. Because the authorization poll enabling the addressable decoder to descramble the purchased event cannot be sent out until after the order has been processed, the addressable controller's capability becomes the limiting factor.

Most one-way addressable controllers in use today are designed to poll large terminal bases sequentially, but polling on individual terminals to enable single event can take as long as 2-6 seconds. Consequently, although the order processing system may accept 2,880 orders in 30 minutes, it is likely that the addressable controller will only enable 600 of these terminals in the same period of time.

ANI (Automated Number Identification)

AT&T and Pacific Bell are currently launching market tests of ANI ordering systems with Viacom, Showtime/The Movie Channel, Zenith, and Cabledata, to acquire practical field experience applying this technology to PPV. Through special switching networks the telco handles a much larger volume of calls than is possible with conventional dedicated telephone lines into the cable system's office, and passes the data to the operator's billing computer for processing and terminal authorization through the addressable controller.

The subscriber dials a special telephone number (on either a rotary or a push button phone), which identifies the call as an order for an event, and then identifies the event being ordered. The subscriber's incoming phone number is recorded by the telco computer, and along with the ordering information, is passed to the operator's billing computer (especially enhanced and modified for this application) for a match to the addressable terminal ID.

The subscriber's interaction with the ordering system is complete once the ANI computer receives the order. If the biling computer cannot process the order (e.g., for poor credit, or inability to match the caller's originating phone number to a terminal ID), a CSR must call the subscriber back to complete or abort the transaction. The subscriber's verification that the event has been proprly ordered comes when the program begins.

AT&T is presently capable of feeding approx. 240 orders per minute (per line) to the billing computer, but this real-time system is still gated by the billing computer's order processing time, and the capacity of addressable controller. With the Zenith Intel controller's limitation of polling 900 terminals in a 30 minute period, most of the ANI system's additional capacity is wasted. Again, only four of the eight sample systems in Figure (4) would be accommodated, at current system size. Fully expanded, all systems would be limited if a 50% peak load occurred in the last 30 minutes.

Both software and hardware enhancements will increase the capacities of the addressable controller currently in use, but at no small expense to addressable system manufacturers and the billing cmpanies with which they are interfaced. Some operators may find it necessary to upgrade both addressable controllers and billing systems in order to derive the benefits that ANI can offer.

Two-Way Interactive Converters

The most notorious of the two-way addressable systems, QUBE, also boasts the truest impulse purchase capability. Although it is a real-time system, QUBE's exceptionally high speed data (256K bps) enables instantaneous PPV orders to be transacted between the subscribers converter and the operator's headend, eliminating the traffic jam problems inherent in all other real-time based systems.

Two-way addressable systems enable the cable operator to satisfy last-minute subscribers' PPV purchases, and to get the most mileage from PPV programs and events. Rather than artifically distribute the PPV load over a longer period of time (as dictated by the limitations of non-impulse ordering mechanisms), these systems can accommodate virtually any volume of orders as they come in. (One operator reported as high as 50% of her PPV orders in the last 15 minutes, another claimed 80% in the last half hour). The capacity to accommodate these incremental subscribers brings in the additional revenue tht makes PPV a successful business.

But the costs associated with two-way interactive plant maintenance expenses have inhibited this approach from gaining widespread popularity in the cable industry.

Store & Forward

Because it is a non-real time pre-authorization ordering system, the store and forward approach to PPV offers the subscriber instantaneous access to PPV programming, yet does not require high speed data (with its associated hardware costs) to provide communication between the subscriber's terminal and the headend/business office. Event-ordering credit limits are downloaded in the one-way addressable command stream on a sub by sub basis, and the terminals are pre-authorized for viewing of those events. When a PPV program is about to begin, the subscriber simply selects the program on the converter and uses an authorize code or command on the converter to verify the purchase. As long as the subscriber is within the prescribed credit limit for this event, it is immediately descrambled, without any real time communication with the cable operator. Since the terminal has already been pre-authorized, no bottlenecking occurs with multiple orders queuing up for authorization polls through the addressable controller.

Once purchased, the event ID is stored in the terminal's memory for retrieval at a later time by the addressable controller. This reporting-back to the headend can be done by cable return, or by telephone for one-way systems. Through a downstream command from the controller, each terminal is requested to report back the contents of its memory. For hybrid, telephone return systems, this command is typically sent during off-peak telephone usage periods, when a dialer in the terminal will respond on the subscriber's telephone line. If the line is in use when the terminal is asked to respond, a "no answer" status is logged for the unit, and it will be tried again later, after the other terminals in the system have reported back. Repeated "no answers" from a terminal raise a flag to the operator that further investigation is required.

The store and forward approach is being used by several addressable converter manufacturers, notably Pioneer, Jerrold, Tocom, and Scientific Atlanta (in development). Interestingly, three of these four manufacturers have also produced two-way interacive systems.

Pioneer's PULSE system is an add-on device that upgrades the BA5000 one-way addressable converter to store and forward impulse PPV capability. The unit is bolted to the converter, and through a bus connection to the BA5000 micro-processor, becomes an integral part of the addressable converter. Consequently, the tamper detection circuit which disables the BA5000 when opened is also activated if the PULSE unit is tampered with, rendering even basic programming unviewable. An additional security measure built into the PULSE is a battery back-up to keep the unit's memory intact and retrievable by the cable operator for up to nine years -- even after the terminal has been disconnected -- thwarting attempts at preventing the PULSE unit from reporting back.

Although approaches vary between manufacturers, several features distinguish the complete integration of those products developed for a pay-per-view environment.

A unique and significant advantage of the store and forward application in some addressable systems is its compatibility between VCR's and PPV programming. The converter program timer can be set to authorize a PPV event in the subscriber's absence. By synchronizing with the VCR timer, the subscriber can purchase and record a PPV program without being at home to initiate the order.

The parental control override of PPV CHANNEL ACCESS gives the subscriber control over unauthorized orders by children or babysitters. This is an important distinction to note between the impulse PPV systems and those relying on telephone calls or stand-alone dialers; secure ordering mechanisms can prevent CSR tie-ups in billing disputes that result from unauthorized orders.

To further assist the operator in determining whether a subscriber actually viewed a particular event that may be claimed to have been selected in error, some store and forward products record the first full 15 minutes of viewing time on the program's channel, giving the operator a hard record with which to combat any subs who attempt to "beat the system" by denying intent to buy. this feature's use should be infrequent, but it obviates the need to develop elaborate operational measures to combat the same problem.

In addition to a 20-event register for PPV events, a desirable feature is the capability to store and report terminal status as codified by the converter's auto-diagnostic function. Another register retains subscriber responses to opinion-polling, and can be utilized for other transactional services, such as shop-at-home, catalog/information requests, etc.

Perhaps the most significant application of store and forward technology outside of IPPV is its "system snapshot" feature. A "record" command can be sent to every addressable converter in the system instantaneously, whereupon each unit will record terminal status for that particular point in time: whether or not the terminal is on, and what channel it is tuned to. This operation can be repeated successively up to five times, in intervals as short as several seconds. Obvious applications are for juxtapositon of programming, provision of accurate viewer information to program-rating services, and ad sales. Naturally, the latter functions must be managed with sufficient care and discretion to prevent community ill will--but cable operators now have the capability to use any of these discretional features at their option, even in one-way cable plant.

Store and forward ordering mechanisms require enhancement of the addressable controller system to retrieve and process the incoming information and to feed the necesary data back into the billing computer; but since these functions can be performed at a far more leisurely pace than for real time systems, the enhancements are relatively simple and economical.

The user friendliness derived from store-and forward systems contributes to the incremental revenues from impulse buyers, and as the matrix in Figure (5) illustrates, capability for peak order load is unlimited.

CONCLUSION

An evaluation of the peak order volume requirements outlined in Figure (5) for varying penetration levels and system sizes is useful in deciding which PPV ordering mechanisms is most appropriate for a cable system's pay-per-view plans. It is apparent from the peak load distribution matrix that although systems such as voice response and ANI may provide short term, low cost entry to the PPV market, impulse-capable technologies must ultimately be employed to allow for successful market penetration of PPV programming.

Order-taking capabilities vary somewhat among the real time based systems, with the true gating factor resting on the addressable controller. At the optimal terminal authorization rate of 30 terminals per minute, all the ordering mechanisms which rely on queuing up terminal ID's for real time authorization are subject to the same system constraints. These systems (CSR call-in, automated voice response, standalone dialer systems, and ANI), can authorize 900 terminals per half hour, or 1800 per hour at the current state of the art in addressable controllers.

A practical limitation is thereby placed on the peak load handling capabilities of the system, irrespective of order-taking capacity. A 30,000 addressable subscriber base on one of these ordering systems must plan a pay-per-view program not to exceed the 6% penetration mark for a peak order load of 50% in a 30 minute period. If, through special marketing and promotional efforts, this 50% peak load can be distributed over 60 minutes, the system shoot for a maximum of 12% penetration for a particular event, and be able to handle the 1,800 terminal authorizations in one hour.

Blockbuster events and heavily promoted new releases which have typically enjoyed penetration rates from 15-60% in many PPV systems, must be offered with one of the ordering mechanisms capable of handling the peak load just prior to event start, in order to maximize the sales potential of the program.

Alternately, if limited by the ordering mechanism technology, a system operator must face the duplicitous task of discouraging a particular set of subscribers from buying the event offered.

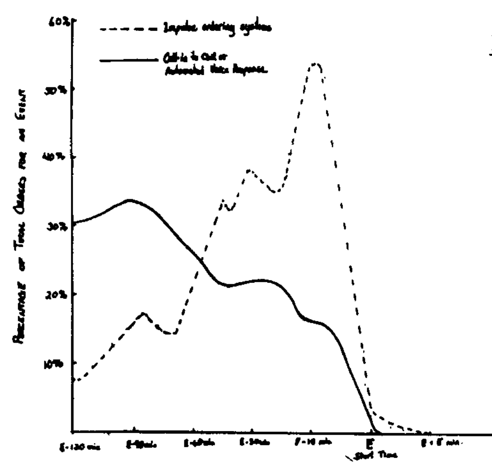
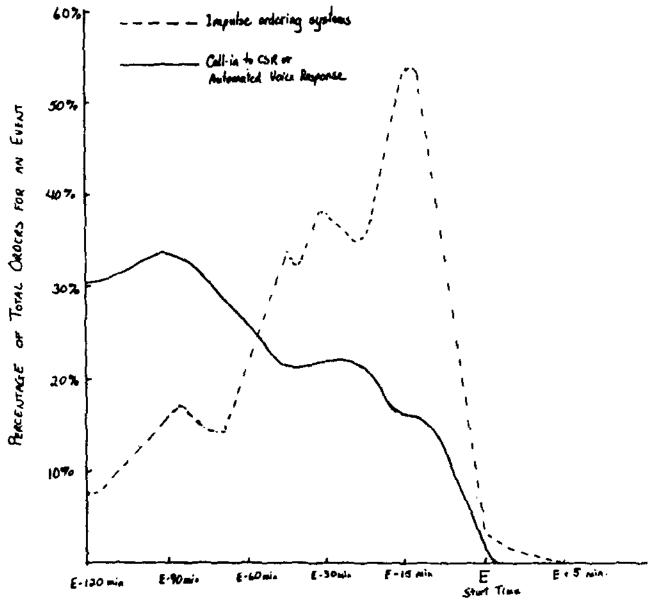


FIGURE #3

Peak Load Distribution of PPV Events in Addressable Systems

cont'd

FIGURE #3 (enlarged)



Peak Load Distribution of PPV Events in Addressable Systems

FIGURE #5

50% PEAK LOAD DISTRIBUTION MATRIX

Addressable Subscribers / Event Penetration	2%	3%	4%	5%	6%	7%	10%	12%	15%	20%	25%	30%	35%	40%	45%	50%
10000	100	150	200	250	300	350	500	600	750	1000	1250	1500	1750	2000	2250	2500
15000	150	225	300	375	450	525	750	900	1125	1500	1875	2250	2625	3000	3375	3750
20000	200	300	400	500	600	700	1000	1200	1500	2000	2500	3000	3500	4000	4500	5000
25000	250	375	500	625	750	875	1250	1500	1875	2500	3125	3750	4375	5000	5625	6250
30000	300	450	600	750	900	1050	1500	1800	2250	3000	3750	4500	5250	6000	6750	7500
40000	400	600	800	1000	1200	1400	2000	2400	3000	4000	5000	6000	7000	8000	9000	10000
50000	500	750	1000	1250	1500	1750	2500	3000	3750	5000	6250	7500	8750	10000	11250	12500
60000	600	900	1200	1500	1800	2100	3000	3600	4500	6000	7500	9000	10500	12000	13500	15000
75000	750	1125	1500	1875	2250	2625	3750	4500	5625	7500	9375	11250	13125	15000	16875	18750
80000	800	1200	1600	2000	2400	2800	4000	4800	6000	8000	10000	12000	14000	16000	18000	20000
90000	900	1350	1800	2250	2700	3150	4500	5400	6750	9000	11250	13500	15750	18000	20250	22500
100000	1000	1500	2000	2500	3000	3500	5000	6000	7500	10000	12500	15000	17500	20000	22500	25000
110000	1100	1650	2200	2750	3300	3850	5500	6600	8250	11000	13750	16500	19250	22000	24750	27500
125000	1250	1875	2500	3125	3750	4375	6250	7500	9375	12500	15625	18750	21875	25000	28125	31250
150000	1500	2250	3000	3750	4500	5250	7500	9000	11250	15000	18750	22500	26250	30000	33750	37500
200000	2000	3000	4000	5000	6000	7000	10000	12000	15000	20000	25000	30000	35000	40000	45000	50000

This distribution matrix assumes a 50% peak load of event orders in the designated time period.

Load limitations of various ordering mechanisms are drawn into the matrix, and shaded by technology.

Peak load distributed over 30 minute period/all controller-gated real time systems (CSR call-in, automated voice response, auto-dialers, and ANI)

Peak load distributed over 60 minute period/ all controller-gated real time systems

Peak load capacity over 30 minute period/impulse capable and store and forward systems

ANI - Strategically Attractive But Can It Handle Impulse Pay-Per-View

by

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GENERAL INSTRUMENT CORPORATION

ABSTRACT

Many issues must be considered by cable operators making a decision between an Automatic Number Identification (ANI) based approach to pay-per-view and a store and forward based approach. These include initial capital outlay, ongoing transaction costs, ease of use and its impact on buy rates, security, compatibility, availability, third party dependency, headend and billing system load limitations, and telco peak capacity. This paper briefly analyzes one and only one of these issues - can the local telephone office, utilizing ANI, handle the peak load generated by a succesful impulse pay-per-view business ?

INTRODUCTION

Automatic Number Identification (ANI) has been proposed to solve a chronic problem of early telephone based pay-per-view services - telephone system congestion. Congestion caused by last minute order calls has been bad for both the cable operator and the local telephone company. Cable operators have lost potential business and aggravated customers, and the local telco has had basic phone service degraded or even disrupted.

ANI attacks this problem in two ways. First and foremost, it does not pass ordering traffic through the local switch. Rather, the primary resource in the local class 5 telephone office used to handle these calls are Customer Digit Receivers (CDRs). These units generate dial tone and interpret touch-tone or dial-pulse dialing commands. When a call is identified by the CDR as a pay-per-view order, usually by an assigned prefix such as *85 or a unique exchange code, special software installed in the office interprets the order command directly from the subsequent dialing sequence. The command is then relayed to the cable operator via a dedicated data link. This leaves the actual switching resources free to handle normal telephone calls.

An additional benefit of ANI over traditional methods comes from the relatively short holding times. In its simplest embodiment, where the system does not wait for real-time credit verification and a short order confirmation tone is transmitted rather than a recorded announcement, holding times can be kept as short as ten seconds.

Thus, the critical demand made on the local telephone office has been estimated at 10 call-seconds of CDR time per PPV order. (A call-second is the standard measure of holding time and represents, on aggregate, one call lasting one second. Thus, 100 call-seconds could be generated by one call lasting 100 seconds or 10 calls each lasting 10 seconds.)

HOW MUCH IS TOO MUCH ?

Is 10 call-seconds per order a lot or a little ? This depends on four factors. These are :

1) How many orders will popular events solicit.
2) What fraction of these orders will come in the last minute or minutes prior to an event.
3) What background load of telephone traffic will the local telephone office be handling when the PPV orders come in.
4) How does the total load placed on the available CDRs by PPV orders, plus the normal telephone traffic load, compare to the design limits of the telephone office.

This paper will closely examine these four factors, quantitatively describing their interrelationships. This analysis makes two important assumptions. First, it assumes that the telcos, or at least the Public Utility Commisions, will find it unacceptable to have normal telephone service disrupted by pay-per-view ordering on any kind of a regular basis. Second, it assumes that customary safety margins will be adhered to in system design to avoid long term degradation of normal telephone service - principally exhibited in this case by abnormally delayed dial tone. The conclusions arrived at here will, of course, be mitigated to the extent that these conditions are relaxed.

HOW MANY ORDERS ?

This brings us to our first attempt at predicting the future. How succesful will pay-per-view be ? Previous experience might serve as a guide with event penetrations running as high as 10%, however, the PPV industry can not be treated as a fully mature business. New services are being launched at a steady pace soon to be augmented by sustained national marketing and promotion. Some program providers even predict that in the not too distant future pay-per-view services may obtain rights to new movies before the video cassette rental stores. Multiple PPV services are also likely to become available on many systems, just as multi-pay services are available today. In these cases, total event penetrations at a given time slot must be considered when projecting loads.

Overall, prudence dictates that the analysis be performed at a fairly wide range of penetration levels. In the succeeding analysis, therefore, the effect of maximum event penetration (measured as the percent of cable subscribers that take a pay-per-view event or events during the most popular time slot) will be examined over a range from 10% up to 30%.

HOW IMPORTANT IS LAST MINUTE ORDERING ?

Addressing the second issue, that is, estimating the fraction of last minute orders, is the most subjective part of this exercise. Rather than trying to predict gross behavior patterns (will consumers buy the product), we are trying to predict detailed behavior patterns (how will consumers want to buy the product and what will they put up with if they have no alternative.)

Ideally, buying a pay-per-view program should be as easy and as natural as changing the TV channel. Anything else is a compromise, perhaps a necessary compromise given the limitations of technology, but nonetheless a compromise. People are not in the habit of placing an advanced reservation to watch a TV show the way they would to go to a restaurant. In general, the TV comes on after dinner, stays on until bedtime, and the dial spins during commercial breaks, landing on the most attractive alternative.

The ideal demand function for pay-per-view ordering, therefore, will probably look a lot like the sharper curve shown in figure 1. The bulk of the orders will come during commercial breaks between network time slots. In fact unless disincentives are placed on the consumer, all of the ordering will gravitate toward the last five minutes before the event.

EXAMPLE DEMAND FUNCTIONS

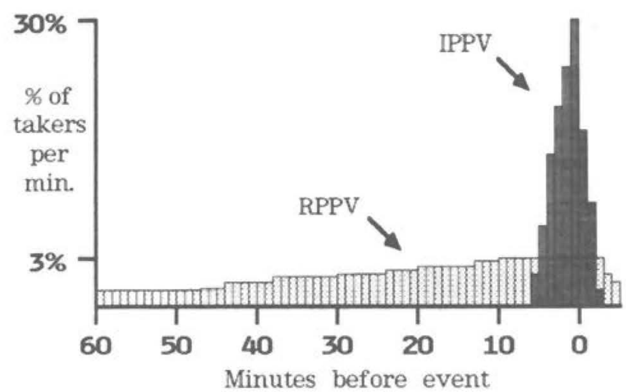

Figure 1

A system that can accommodate this sharp demand is by definition an impulse pay-per-view (IPPV) system. A system that cannot accommodate this type of demand and must, in one way or another, get the consumer to reserve the program in advance is a reservation pay-per-view (RPPV) system. The flatter curve in Figure 1 shows an RPPV demand function.

There is no doubt that ANI can handle RPPV, even at optimistic penetration levels. In fact, ANI may be overkill. In many cases, a well managed Automatic Response Unit (ARU) approach utilizing standard phone lines may be sufficient for RPPV. The question posed by this paper, however, is can ANI handle impulse pay-per-view. In the succeeding analysis, therefore, the effect of peak order rate (expressed as the maximum percent of total event takers that order in any given minute prior to the beginning of the show) will be examined over a range from 10% to 30%.

WHAT ABOUT NORMAL PHONE TRAFFIC

An important consideration in analyzing an ANI system's capacity is estimating the load that normal telephone calls place on the central office CDRs during periods when pay-per-view programs are likely to be ordered. This traffic is well characterized. Residential telephone traffic has its peak between 9:00 AM and 10:00 AM, and then stays fairly constant until the evening hours, when it peaks between 7:00 PM and 8:00 PM (1). The morning peak generates on the average one call per telephone line during the busy hour, while the evening peak averages about 70% of this. It is this evening peak that coincides almost precisely with the beginning of prime television viewing time.

A typical telephone call will tie up a central office CDR for about 15 seconds, somehat longer than that estimated for an ANI PPV call. Peak load, then, will be about 15 call-seconds per line during the morning busy hour and 10.5 call-seconds per line during the evening busy hour.

WHAT IS THE TOTAL LOAD

We can now add up the total load on the CDRs and compare it to the nominal design limit for a typical class 5 office in a residential neighborhood. The calculation will be performed for a median size 1A ESS of 24,000 lines (i.e., 24,000 telephone subscribers), although the results should roughly scale proportional to the number of lines for larger or smaller offices. Large cable systems, of course, could require the support of many telephone offices.

First, what is the nominal peak CDR load to which the example office is designed ?

Peak CDR Load = 15 call-sec./line/hr. x 24,000 lines
= 3600 CCS/hour
= 100 Erlangs

(For convenience, traffic intensity will be expressed in Erlangs, which is a dimensionless unit equal to one call-hour per hour or one call-second per second, etc.)

The next question is, how many CDRs are required to handle 100 Erlangs of peak load at a standard service level of p = .01. (A p = .01 service level ensures less than a 1 in 100 chance of not finding a CDR available when one is required.) Using the usual assumption of random arrivals, a standard Poisson Traffic Table (2) indicates that 125 CDRs will be needed. Additional CDRs are often installed beyond the nominal peak requirement as an added safety margin. As stated previously, however, we will assume that safety margins are not going to be relaxed simply because PPV has been added. (Thus would result in an implicit cross subsidization of cable subscribers by telephone rate payers, a practice frowned upon by various regulatory agencies.) Thus, any incremental ANI traffic that drives the total peak load on the CDRs above 100 Erlangs in our example case must eventually result in increased investment in CDRs, paid for by ANI customers.

Fortunately, the evening peak reaches only 70% of the morning busy hour, or roughly 70 Erlangs of CDR traffic. This leaves 30 Erlangs of "idle" capacity to handle pay-per-view. Is this enough ?

The tables on the next page show the incremental load generated by IPPV traffic for three penetrations of cable subscribers - 35%, 50%, and 65% of homes passed. Homes passed is related to central office size, in our example, by assuming that 85% of the telephone lines are primary residential lines, the rest being business lines or second telephones. In each case, the generated load is calculated for maximum event penetrations ranging from 10% to 30% of cable subscribers and peak order rates ranging between 10% and 30% of total event takers per minute. Average CDR holding times are kept constant at 10 seconds. (Longer average holding times will, of course, increase the IPPV load proportionately.)

Each entry in the tables is expressed in Erlangs and is calculated by the following simple formula.

CDR load (Erlangs) = size of central office (# of lines)
x primary residential line factor (%)
x cable penetration (% of hp)
x max. event penetration (% of subs)
x peak order rate (% of takers/min.)
x CDR holding time (sec.)
x 60 (seconds/min.)

ANI CDR LOAD TABLES

FIXED PARAMETERS :

SIZE OF CENTRAL OFFICE	- 24,000 LINES
% PRIMARY RESIDENTIAL	- 85 PERCENT
CDR HOLDING TIME	- 10 SECONDS
NOMINAL "IDLE" CAPACITY	- 30 ERLANGS

ALL RESULTS EXPRESSED IN ERLANGS

CASE 1

CABLE PENETRATION	- 35 PERCENT
NO. OF CABLE SUBS IN C.O.	- 7,140 SUBS

Maximum Event Penetration (% of subs)	Peak Order Rate (% of Takers) 10	15	20	25	30
10	12	18	24	30	36
15	18	27	36	45	54
20	24	36	48	60	71
25	30	45	60	74	89
30	36	54	71	89	107

CASE 2

CABLE PENETRATION	- 50 PERCENT
NO. OF CABLE SUBS IN C.O.	- 10,200 SUBS

Maximum Event Penetration (% of subs)	Peak Order Rate (% of Takers) 10	15	20	25	30
10	17	26	34	42	51
15	26	38	51	64	76
20	34	51	68	85	102
25	42	64	85	106	128
30	51	76	102	128	153

CASE 3

CABLE PENETRATION	- 65 PERCENT
NO. OF CABLE SUBS IN C.O.	- 13,260 SUBS

Maximum Event Penetration (% of subs)	Peak Order Rate (% of Takers) 10	15	20	25	30
10	22	33	44	55	66
15	33	50	66	83	99
20	44	66	88	110	133
25	55	83	110	138	166
30	66	99	133	166	199

[ ] - Below "Idle" capacity   [dotted] - Exceeds "Idle" capacity

As can be seen, a significant range of loadings exceed the "idle" capacity of the example office. In Case 2, where cable penetration equals 50% of homes passed, if an event or simultaneous events achieve a 20% penetration and 20% of these event takers call in the last minute, 68 Erlangs of CDR load are generated. ***This load is more than twice the "idle" capacity of that office.*** Keep in mind that this example only represents 408 people out of 10,200 subs calling in the last minute.

The situation gets progressively worse as penetration and impulse ordering goes up. Attempts to directly shed this load by immediately disconnecting PPV callers when they dial their first prefix digit (e.g., *) will not only result in lost orders and aggravated customers, but could lead to potentially unstable situations as callers repeatedly attempt to get through.

CONCLUSION

One is drawn to conclude from this analysis that ANI was designed for reservation pay-per-view, not impulse pay-per-view. To expect idle central office resources to accomodate significant impulse ordering is unrealistic. In our example, a doubling in the number of CDRs could be required. Unfortunately, small scale field trials may not reveal problems that could become serious during a full scale rollout. Convincing customers to order in advance will also become more and more difficult as the volume of pay-per-view offerings goes up, with each show recieving a proprotionately smaller share of advanced promotion.

Cable operators and equipment suppliers should closely examine their traffic assumptions. While an additional investment in central office equipment can certainly alleviate overload problems, this investment must ultimately be reflected in transaction costs. It is unclear whether the current estimates of $.25 to $.50 per call reflect these costs. A careful analysis of ANI tariff filings should help resolve this issue. Meanwhile, cable operators should not foreclose alternatives that might better meet their long term needs.

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BTSC: THE STEREO FOR CABLE

by

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ABSTRACT

Stereo programming is presently available to the cable operator. The enhanced entertainment value of stereo video programs should be provided to the cable subscriber as soon as possible in order to stay competitive. BTSC is the best choice of stereo formats for video program audio because of the ease of interface and compatibility, both in the headend and the home. Video buzz interference has been the major drawback to BTSC stereo, but it has been eliminated with the dual detector system. Other limitations such as bandwidth and separation are minimal and turn out to be audibly insignficant. BTSC stereo has a better dynamic range than the typical FM stereo receiver. BTSC requires no separate tuning system as out of band FM systems do, which makes BTSC the easiest to operate and the least expensive alternative.

INTRODUCTION

Quality stereo audio is a significant enhancement to the entertainment value of any video source. Cable television should be no exception. In a time when competition from video tape rentals is strong (many of which are in a hi-fi stereo format) cable must move quickly to provide stereo. The BTSC format is compatible with broadcast, cable, and home equipment. Broadcasters in many areas are presently transmitting in BTSC stereo, but their source of stereo programming is still limited. Cable operators have an advantage over broadcasters, in that many pay services are already available in stereo.

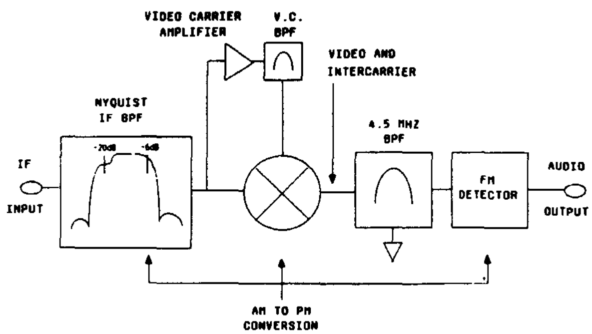
BTSC is the most convenient means available to the cable system operator for providing multi-channel television sound. Passing the BTSC signal through to the subscriber on broadcast channels usually requires no changes. To put a satellite channel in BTSC stereo requires a subcarrier receiver and a BTSC encoder/modulator. The result of this small addition to the headend is an enhanced service which requires no truck rolls and no additional subscriber equipment provided by the cable operator. The subscriber interested in stereo may purchase a stereo TV or stereo adapter. The cable operator may choose to sell or lease stereo adapters. BTSC adapters do not require tracking tuning or separate tuning by the subscriber as out of band stereo systems do. BTSC provides increased customer satisfaction and an opportunity for increased revenue and pay service retention.

BTSC SYSTEM PERFORMANCE

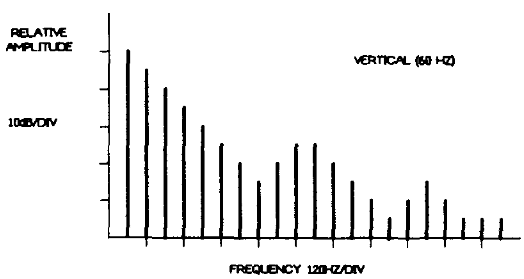
BTSC has been criticized by some in the industry for being a system with inferior audio quality. I contend that the BTSC system is the best choice in a backward compatible environment. The poor quality claimed is a result of early non-optimum encoders, modulators and inferior receiver designs, as well as improper equipment alignment and operation.

Video Interference

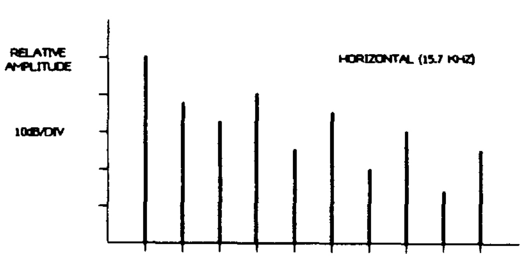
Video Interference has been the major limiting factor in most BTSC measurements and listening tests. The primary problem area is in the BTSC receiver, which exhibits high buzz interference levels. The buzz is a result of AM to PM conversion in the Nyquist intercarrier detection system commonly used (see Figure 1). Some of the AM video modulation present on the video carrier is converted to phase modulation of the sound carrier in the detection process which results in video spectra overlapping the audio information. This overlap occurs at video vertical rate (see Figure 2) and harmonics, as well as horizontal rate (see Figure 3) and harmonics. The horizontal interference also has vertical rate sidebands (see Figure 4). Monaural TV receivers with small speakers were usually not bothered greatly by intercarrier buzz, having most of its energy outside the TV sound systems' bandwidth on both ends.



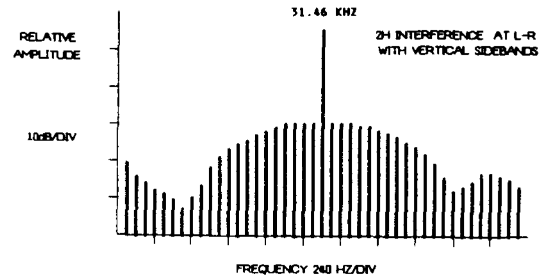
INTERCARRIER DETECTOR FIG. 1



VIDEO INTERFERENCE FIG. 2

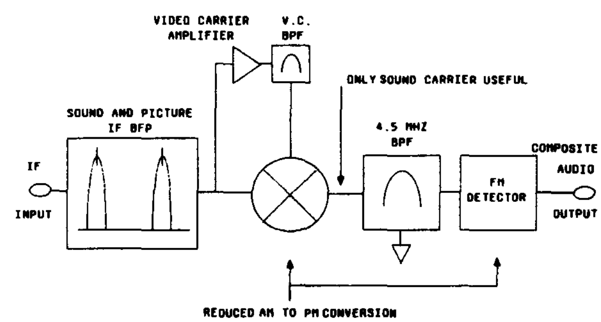


VIDEO INTERFERENCE FIG. 3



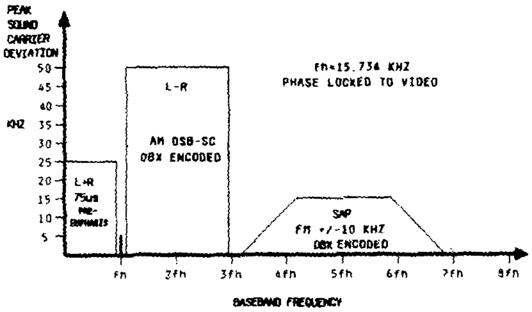
VIDEO INTERFERENCE FIG. 4

There are techniques which reduce the level of the intercarrier buzz components. The Quasi-Parallel (Q-P) sound system (see Figure 5) is significantly better than the Nyquist system because of the reduced AM to PM conversion of the video carrier due to the symmetrical filtering. The choice of FM detectors can also have a significant impact on buzz level. AM rejection is very important.

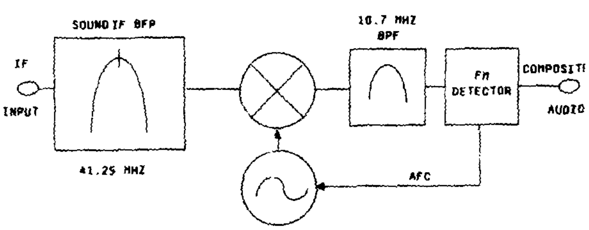


QUASI PARALLEL DETECTOR FIG.5

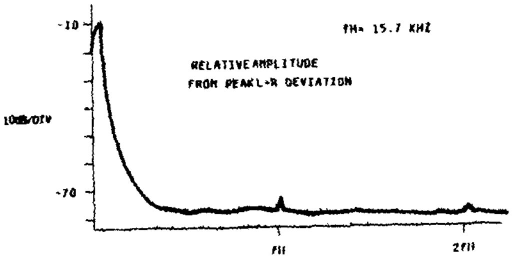
Although the Quasi-Parallel technique is an improvement, it does not eliminate the video interference at horizontal frequency and its harmonics. Both the TV transmitter or modulator and the Q-P intercarrier receiver have residual levels of AM to PM conversion. The BTSC spectrum (Figure 6) Pilot, L-R, and SAP carriers are centered exactly where the highest level of video interference falls. In order to achieve buzz free stereo sound, another detection scheme is required. The obvious way to eliminate video interference is to detect the sound carrier independent of the video carrier. This approach is known as separate sound detection (see Figure 7). This system works extremely well for high frequencies (i.e., Pilot, L-R, SAP - see Figure 8), but exhibits a severe problem at low frequencies, i.e, L+R (see Figure 9). The low frequency noise is a result of the oscillators used in the converter's tuning process. The separate sound detection system is unacceptable except where oscillators of instrument grade phase cleanliness are used. This is not the case in CATV converters, TV receivers, and sometimes TV modulators.



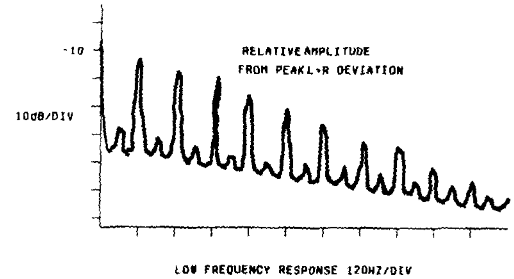
BTSC SPECTRUM FIG.6



SEPERATE SOUND DETECTOR FIG.7



SEPERATE SOUND DETECTOR OUTPUT FIG. 8



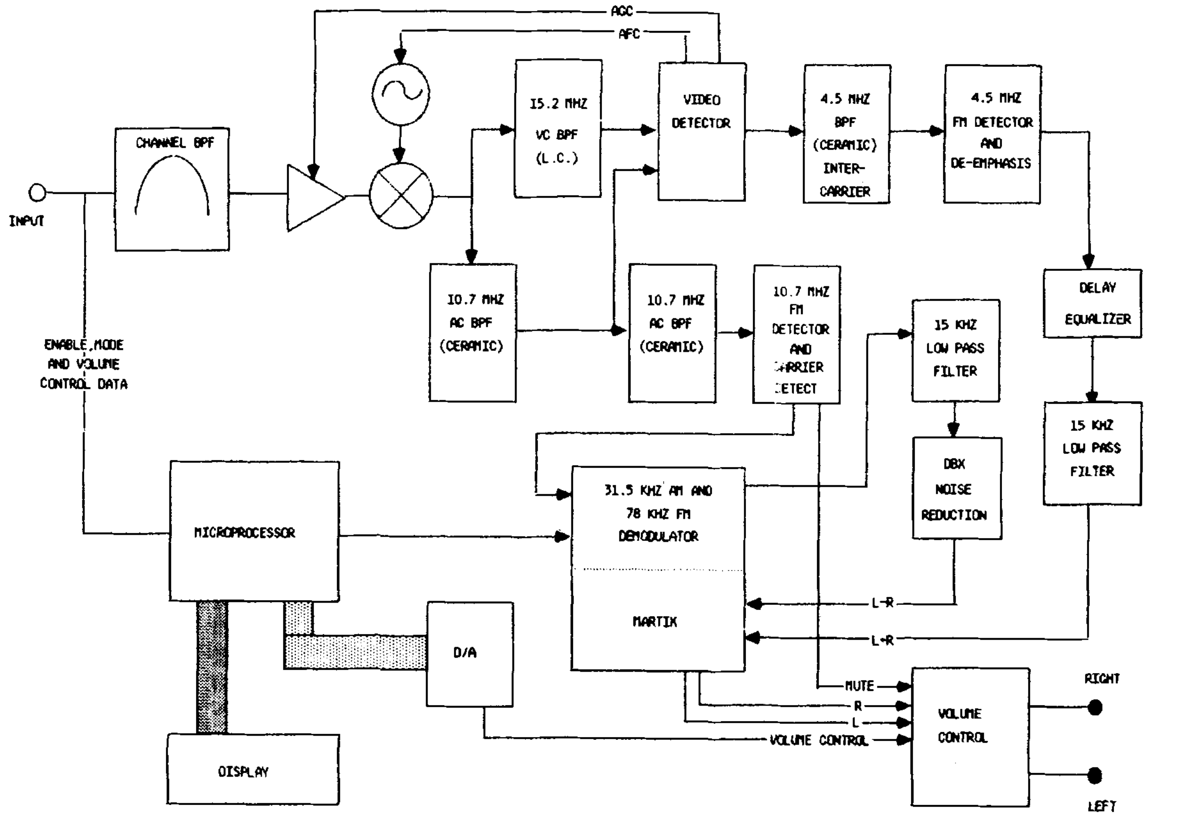
SEPERATE SOUND DETECTOR OUTPUT FIG. 9

<u>Dual Detector System</u>

<u>A Dual Detector System</u> is the solution to the conflicting problem of either high or low frequency noise by using both types of detectors simultaneously. A dual detector system consisting of a Quasi-Parallel detector for the L+R component and a separate sound detector for the Pilot, L-R and SAP components gives superior performance. Not only is the buzz problem eliminated, but channel separation is also improved. Because there is no interference component falling on the pilot, its phase relationship to the L-R subcarrier remains unaltered. In addition, the bandwidths of the two receivers can be independently tailored for matched L+R and L-R delays. Figure 10 is a block diagram of one implementation of a dual detector BTSC stereo receiver.

BTSC receivers which do not use dual detectors still offer a substantial improvement in sound impression over the typical monoral TV receiver. The L-R buzz is usually well masked by the dBX [TM] noise reduction. The buzz is, however, audible, especially in intermittent quiet situations such as drama, sports dialog, or orchestra concerts. For BTSC to reach high fidelity standards, a dual detector system is required.

The BTSC system has been compared with high fidelity systems in the cable press, but the BTSC receivers used were not high fidelity types. A high fidelity BTSC receiver requires the same care as a high fidelity broadcast FM receiver. Multiple ceramic filters for high frequency video rejection, advanced quadrature or pulse count FM detectors for high linearity and a linear multiplier for clean L-R detection would be required in order to compare apples to apples. However, BTSC, even in its inexpensive implementations, does exhibit one advantage over the majority of FM stereo



DUAL DETECTOR BTSC RECIEVER

FIG. 10

receivers. The hiss level is much lower due to the dBX noise reduction. This reduced hiss is usually apparent even to the casual listener.

BTSC Measurement

BTSC Measurements are greatly enhanced by the use of a Fast Fourier Transform (FFT) spectrum analyzer. An FFT is superior to analog audio spectrum analyzers because of the very narrow resolution bandwidth achievable while maintaining rapid display updates. An FFT spectrum analyzer is much more useful than a distortion analyzer because individual signal components are immediately distinguishable rather than receiving one summation number. Hum, buzz, harmonic distortion, spurious signals, and random noise are immediately obvious on the FFT analyzer, but often are disguised by a Total Harmonic Distortion Plus Noise (THD+N) reading. A THD+N of 0.5% may have pleasing sound quality or be annoying depending on the source of the 0.5%. Spurious signals 46 dB down are quite obvious against rather pure tones such as piano notes, but second harmonic distortion at the same level is not. For BTSC receivers THD+N numbers don't tell the story. FFT spectrum analyzer photos say a lot.

Channel Separation

Channel Separation capabilities are limited in the BTSC system because only the L-R component is dBX processed. Any tracking errors in the noise reduction processing reduces channel separation when the components are recombined to recover the L and R channels. Separation in practice will generally be greater than 20 dB over the frequency range where separation has significance, roughly 100 Hz to 8 KHz. This does not seem to be a very impressive number by comparison with other systems, but fortunately the audible difference between 40 dB and 20 dB separation is rather insignificant.

Dynamic Range

The Dynamic Range of a currently available dual detector BTSC receiver is 65 dB at 1 KHz. This is by no means a theoretical system limitation. A higher cost implementation could certainly achieve further improvement. For cable applications with limited carrier to noise ratios (C/N), further improvement may be a bit academic. The signal to noise ratio (S/N) of the L+R component at 1 KHz with a video C/N of 40 dB and sound carrier 15 dB down should theoretically be 70 dB. The L-R component, however, would have only 43 dB S/N for the same conditions. The dBX noise reduction system has a masking effect which generally provides about a 20 dB apparent improvement, giving the sound quality of 63 dB S/N.

Bandwidth

The Bandwidth of BTSC audio must be hard limited to 15 KHz to prevent interaction of audio with the fH pilot. The net system -3 dB bandwidth, including the decoder, can easily achieve 13 KHz. Again, there is very little difference between the sound quality of the BTSC 13 KHz and the 15 KHz available in other systems. On the low frequency end BTSC audio is not limited in comparison with other systems.

SUMMARY

It is very important to realize that although BTSC does not challenge the specifications of compact disc players, it can provide good stereo sound for a theater style effect. BTSC sound, in fact, is better than the audio reproduction capabilities in the vast majority of subscriber homes. BTSC stereo is intended for video program related audio rather than separate premium audio services. The ease of interface and low cost cannot be beat. If you are still not convinced that BTSC stereo is a major improvement to the entertainment value that can be delivered by cable, may I suggest that you perform the following experiment. Connect a BTSC stereo receiver to a quality stereo system. Watch and listen to Miami Vice broadcast from a stereo transmitter. You will most likely come away from the test wishing your TV screen was larger to match the depth and impression of your sound.

Acknowledgements

Thanks to General Instrument for supporting an extended investigation of BTSC receivers.

Thanks to Alps Electric Company, Ltd. for an economical implementation with superior performance.

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CABLE STEREO QUALITY: CAN CONSUMERS HEAR THE DIFFERENCE?

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ABSTRACT

Current consumer trends suggest that cable operators must find a way to provide cable subscribers with stereo. Of prime importance in the cable operator decision of how to carry cable stereo is determining how much quality consumers expect from cable stereo. In order to answer this question, ATC and Gillcable undertook a joint study to measure consumer perception of cable stereo quality.

The research results suggest that most consumers will not be able to detect quality differences among alternate stereo delivery systems. This is particularly true for the audio sources most commonly used in cable television programming.

The implication for the cable operator is that quality should be less of a factor in the decision of how to carry cable stereo than the economic and technical restrictions of the individual cable system.

INTRODUCTION

The growing trend for broadcast delivery of stereo television presents cable operators with the challenge of determining the best method for delivering cable stereo. Operators have a number of alternative delivery techniques available, and must choose the method that makes best use of scarce spectrum space and capital dollars while providing a secure signal and a level of audio quality consistent with consumer expectations.

In order to learn more about the relative qualities of cable stereo delivery alternatives, ATC and Gillcable undertook a joint effort to measure both the technical performance specifications of cable stereo equipment and consumer reaction to the relative listening quality of stereo delivered via cable. A discussion of the technical performance results is reported by David Large of Gillcable in a separate paper.

The purpose of this paper is to present the results of the consumer listening tests and to discuss the implications of those results for cable delivery of stereo television.

METHODOLOGY

The research is based on a series of twenty-nine group sessions with a total of 206 Gillcable subscribers 18 years of age and older. Subscribers were pre-screened for stereo equipment ownership and to ensure a 50-50 ratio of male and female participants. Respondents were asked to view TV monitors and listen to audio and then to fill out their responses in self-administered questionnaires. The questionnaires asked them to compare two audio selections and decide how selection "B" compared to selection "A" on a seven point scale from "a lot better" to "a lot worse." The sessions were conducted November 14 through November 23, 1985, in San Jose, California.

Participants viewed three selections of programming, each played twenty times through the various sound systems. The three programs, "Miami Vice" titles, a scene from "Beverly Hills Cop," and a high-separation, audio-only musical piece, were chosen for their varying degree of sound separation and stereo "effects." None of the selections included spoken dialogue.

Equipment used in the research attempted to replicate audio as delivered through a cable system. Figure 1 is a block diagram illustrating the equipment set-up used for the testing.

TEST RESULTS

Ten separate tests were conducted to evaluate consumer preference for alternative cable stereo delivery techniques. We asked consumers to compare the relative quality of:

1. Mono television to stereo television (mono signal).
2. Stereo television in mono mode to stereo television in stereo mode (stereo signal).
3. Separate speakers to in-set speakers (stereo signal).

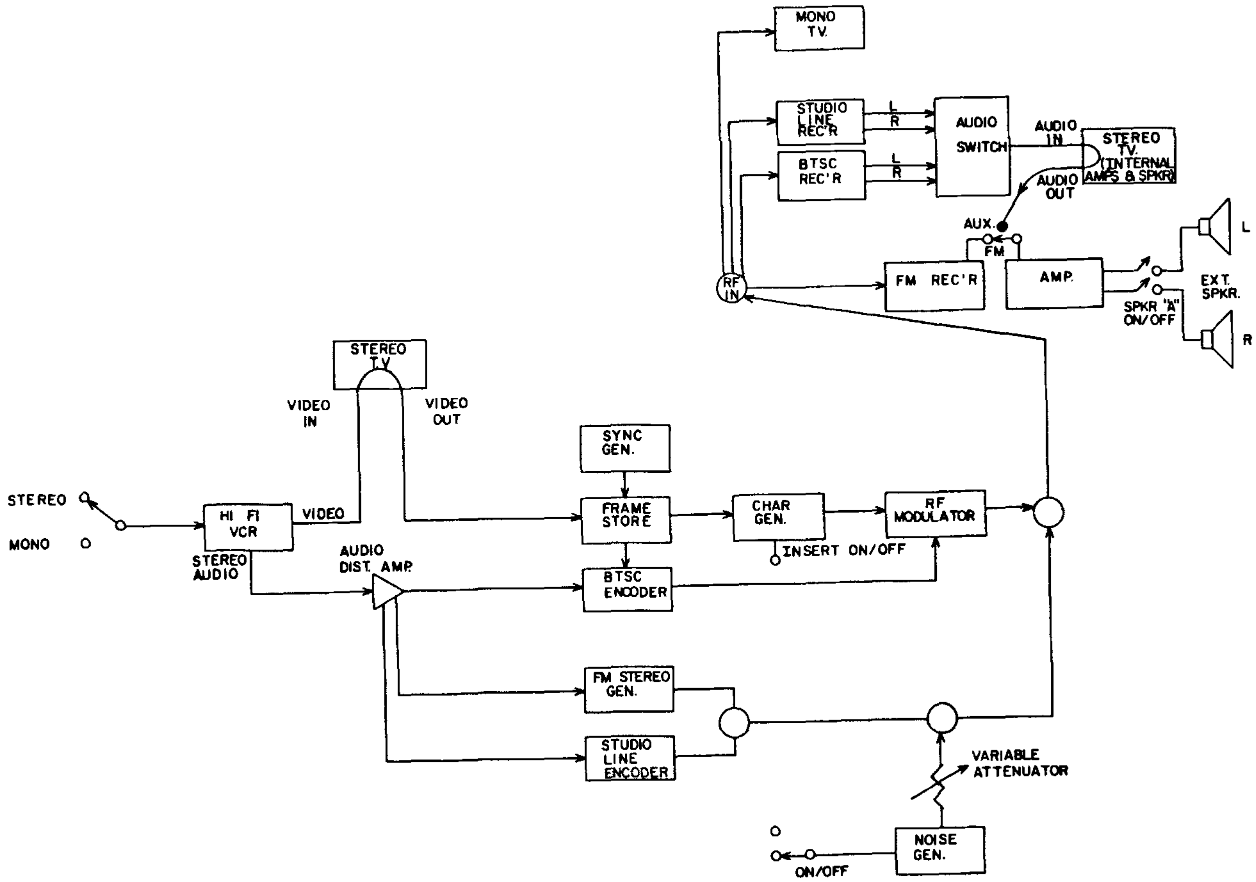

Figure 1. Test Equipment Set-up

4-6. "Clean" signal to degradation as represented by the addition of white noise from a noise generator through a variable attenuator set in increments of 15, 10 and 5 dB. The signal quality decreased as the attenuation decreased.

7. Stereo sound with character generator noise added, to stereo sound without character generator noise added.

8. FM stereo to BTSC stereo.

9. BTSC stereo to Studioline stereo.

10. Studioline stereo to FM stereo.

Evaluation of three of the above listed tests is not complete, and will not be discussed in this paper. In the cases of test six (signal degradation through a variable attenuator set at 5 dB), test seven (character generator noise), and test ten (Studioline stereo compared to FM stereo) difficulties in accurately assessing subtle differences in consumer perceptions require further work. We hope to have confirming tests completed prior to oral presentation of this research.

Program Sources

Three program sources were used throughout all ten tests. Results generated in other consumer listening testing have suggested that an individual's ability to discriminate between varying audio qualities is dependent on their familiarity with the musical format used in the test.[1,2] In an effort to cover all bases we selected programming from the movie "Beverly Hills Cop" to represent "movie" audio, a selection from "Miami Vice" titles to represent broadcast stereo, and an audio-only selection from Jean Michael Jarre's album "Oxygene" to represent very high quality audio without video distraction. The "Oxygene" music in particular has a great deal of stereo separation. All selections were recorded and edited in stereo using the VCR Hi Fi format. Miami Vice and Oxygene were recorded from Compact Disc. "Beverly Hills Cop" was recorded from a VCR Hi Fi cassette.

TEST RESULTS

The testing was divided into two sections: Consumer Reception Equipment and Cable Delivery Systems. Discussion of test results will be organized within these two sections. Because respondents perception of sound quality differed according to the music selection, results will be presented by audio source.

Consumer Reception Equipment

Table 1 presents the results of consumer ranking of the different reception equipment used in the test. In the comparison of a mono signal delivered via stereo TV to mono TV delivery (test 1), consumers clearly preferred the audio from the stereo television to that of the mono TV.

Respondents were less able to distinguish a stereo signal on a stereo TV from a mono signal on the same stereo TV (test 2). For the Beverly Hills Cop and Miami Vice program sources, no strong preference was expressed for the stereo mode, with over half of the respondents expressing no preference at all. Younger respondents (18-34) did indicate a stronger preference for the stereo mode than any other group, a finding consistent with the generally better hearing of younger people. Only in the case of the audio-only program source did most respondents indicate a preference for the stereo mode. The high degree of separation in this program source may have influenced consumer preference.

In test three, consumers were clearly able to distinguish between the audio from in-set TV speakers and separate speakers. Most respondents preferred the audio from the separate speakers. The test results seem to indicate that while consumers can clearly distinguish between a system with good quality speakers and amplifier and the audio from a single three inch speaker, they are less perceptive of the difference between a stereo signal and a mono signal when the reception equipment is the same. This is particularly true when Hi Fi VCR audio and broadcast television stereo are the program sources.

CABLE DELIVERY SYSTEMS

Signal Degradation

As expected, consumers were less able to detect differences between relatively subtle changes in the quality of the stereo signal. Table 2 presents the results of respondent sensitivity to incremental signal degradation.

Test four compares a clean stereo signal to one moderately degraded by insertion through a 15 dB attenuator. The majority of test participants could not distinguish between the two signals. In fact, over 80% said that the undegraded signal was either a little better, exactly the same or a little worse than the degraded signal. Of those respondents noting a difference, the majority preferred the clean (noise off) signal.

TABLE 1

CONSUMER PREFERENCE FOR RECEPTION EQUIPMENT

		Beverly Hills Cop	Miami Vice	Audio Only
The sound was better from:				
Test 1:	Stereo TV (mono mode)	76%	85%	72%
	Mono TV (stereo mode)	15	9	19
	No Difference Detected	9	6	9
Test 2:	Stereo TV (mono mode)	26%	50%	23%
	Stereo TV (stereo mode)	14	20	49
	No Difference Detected	60	30	28
Test 3:	Separate speakers	56%	60%	68%
	Stereo TV In-set speakers	36	35	26
	No Difference Detected	8	5	6

Table 2

CONSUMER SENSITIVITY TO SIGNAL DEGRADATION

		Beverly Hills Cop	Miami Vice	Audio Only
Test 4:	Signal Inserted through 15 dB Attenuator			
	The sound was better with...			
	Noise off	20%	35%	32%
	Noise on	15	18	25
	No Difference Detected	65	47	43
Test 5:	Signal Inserted through 10 dB Attenuator			
	The sound was better with...			
	Noise off	27%	40%	39%
	Noise on	17	26	22
	No Difference Detected	56	34	39

Table 3

CONSUMER PREFERENCE FOR DELIVERY SYSTEM

		Beverly Hills Cop	Miami Vice	Audio Only
The sound was better from:				
Test 8:	FM	39%	47%	40%
	BTSC	33	30	32
	No Difference Detected	28	23	28
Test 9:	Studioline	32%	38%	32%
	FM	28	32	28
	No Difference Detected	40	30	40

More people were able to detect a quality difference between a clean signal and one attenuated at 10 dB (test 5). Still, over 70% of respondents detected very little or no difference between the signals. In both tests four and five, respondents were less likely to perceive any difference when listening to "Beverly Hills Cop" than either of the other two program sources.

Delivery Systems

Table 3 presents the results of consumer ranking of preferences between FM and BTSC (test 8) and of preferences between Studioline and FM (test 9). In test eight, the majority of respondents preferred the FM source to the BTSC source, although almost one-quarter of the respondents could detect no difference and a full one-third preferred the BTSC format. The slight preference for FM may be explained by FM's higher separation compared to BTSC. Ability to distinguish (and prefer) separation is indicated by the more discriminating listening done on the high-separation, audio-only program source and by consumer preference for separate audio speakers.

In a comparison of the Studioline signal and FM (test 9), respondents had more difficulty detecting a difference between the two signals. Eighty percent of test participants ranked their answers in the middle categories of " a little better," "exactly the same," and "a little worse." Of those participants noting a difference, there was a slight preference for the Studioline signal.

CONCLUSIONS

Current retail trends, coupled with the apparent consumer preference for stereo television equipment, suggest that cable operators must quickly find a way to deliver stereo to cable subscribers.

While consumers appear to be able to detect audio quality differences among in-home television equipment, they are less able to detect audio quality differences among alternate cable stereo signals. This is particularly true when the audio program sources are broadcast television stereo or Hi Fi VCR stereo. Most cable television audio programming will not exceed the quality levels found in broadcast television or Hi Fi VCR audio. The implication for the cable operator is that quality of stereo delivery is not a primary factor in determining how to provide stereo audio to cable subscribers. Most cable subs will not be able to detect quality differences even between the highest quality out-of-band delivery technology (Studioline) and a FM delivery system. The decision on how to deliver cable stereo should focus on the technical parameters and the economic factors for the individual cable system and the amount of signal security required. Audio quality should be a secondary factor in the decision process.

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CABLE TELEVISION OPPORTUNITIES IN THE LODGING INDUSTRY WITH IMPULSE PAY PER VIEW TECHNOLOGY

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I. INTRODUCTION

Historically impulse pay-per-view (IPPV) on a broad CATV basis has proven to be impractical. However the technology exists to make impulse pay-per-view practical on a smaller scale if adequate care is taken to ensure that the design best utilizes the existing resources. The commercial MATV environment is an ideal location for utilizing two-way addressability to implement a true impulse pay-per-view entertainment system.

This paper will discuss the technical parameters involved in implementing such a system. Additionally the incorporation of this IPPV system into an existing hotel television system will be discussed.

II. TYPICAL MATV SYSTEM

Television delivery in the lodging industry is typically viewed as a necessary evil rather than an opportunity to increase revenue. Consequently most existing hotel/motel television systems are not built to the standards of quality typically seen in the CATV industry. This has resulted in many serious limitations that must be considered when developing and implementing an IPPV system.

Historically the hotel head-end has consisted of a set of off-air antennas and the associated amplifiers and combiners required to receive local broadcasts. Due to the additional distribution loss at UHF frequencies, UHF stations have been typically converted to unoccupied VHF channels for distribution in the MATV system. Satellite television delivery has prompted many hotel operators to install earth stations.

Most hotels are located in areas that are passed by existing CATV plant. Consequently there is an increasing number of hotels that receive television from CATV drops. Herein lies the opportunity for increased revenue for the CATV system operator. The CATV system can, in effect, take the place of most of the hotel MATV system head-end.

A typical MATV distribution system is entirely passive, consisting principally of RG-59, splitters and taps. The absence of amplifiers results in typical system losses of up to 50dB. Such losses require output levels as high as +65dBmv at the MATV headend. The construction techniques as well as the types of splitters and taps limit useful bandwidth to less than 216 MHz. Roll-off below channel 2 is also common, becoming severe below 20 MHz.

The small size of a typical hotel MATV system, compared with a CATV system, limits the problems with ingress and egress. Therefore the shielding in such a system is minimal. Taps are often unshielded and drop-to-drop isolation can be as low as 10dB. Taps consisting of resistive dividers can result in poor return loss.

III. SYSTEM ARCHITECTURE

The discussion of the hotel MATV system given above suggests several constraints for the design and implementation of a two-way addressable impulse pay-per-view system for the hotel/motel environment. Any hardware that is intended for retrofit into an existing MATV system should require a minimum of modification to that MATV system. The billing interface for the hotel operator should be user-friendly while providing a high levels of security for the programming supplier.

One scheme to implement a true

impulse pay-per-view system requires continuous and rapid communication between the components of the system, especially between the individual guest room and system controller. This scheme has had limited success as such rapid communication is often difficult if not impossible to make happen. Delays in processing a purchase are perceived by the hotel guest as inadequacies in the system.

A more reasonable approach utilizes a distributed intelligence approach to the system. There is a central supervisory computer that periodically monitors the overall system performance. However, there is an intelligent set-top terminal in each room capable of handling all transactions independently of the supervisory computer. Purchase and status information need only be reported by the set-top terminal when it is polled by the supervisory computer. This makes all guest transactions occur instantaneously.

An overall system block diagram describing this approach is shown in Figure 1. The system consists of four major components:

1. Supervisory Computer
2. Premium Programming Interface
3. Data Interface
4. Set-Top Terminal

SYSTEM BLOCK DIAGRAM

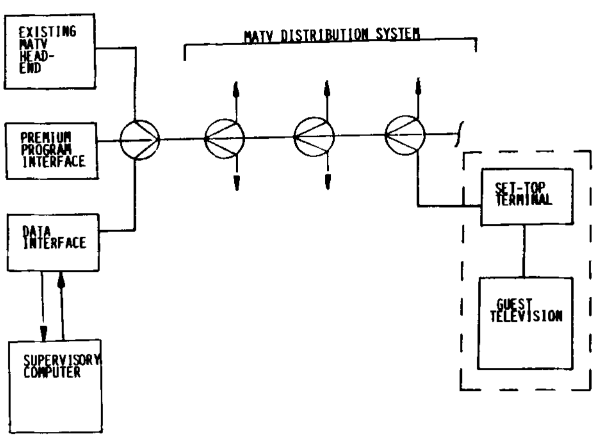

FIGURE 1

The Supervisory Computer controls overall system operation and acts as a billing interface for the hotel operator and/or programming supplier. The premium programming interface combines the actual premium programming material with the other programming on the existing MATV system. The Data Interface handles communication between all system components providing among other things the data link between the Supervisory Computer and the Set-Top Terminals. The Set-Top Terminal (STT) acts as programming selector and purchase point for the individual hotel guest. These components will be discussed in greater detail later.

In order to best utilize the available bandwidth without rebuild, the system should be designed with delivery of the supplemental or premium programming in the VHF midband (channels B thru H). This selection of band plan allows delivery of supplemental programming utilizing the same cable as premium programming and minimizes the requirements for existing MATV system rebuild and upgrade. Channel I is unused to provide a guardband between standard and premium entertainment.

Data communications should be implemented over two RF channels, carried over the same cable as the standard and premium programming. One channel would carry downstream communication consisting of inquiries and system configuration commands from the Supervisory Computer to the STTs. The other channel would carry upstream communications consisting of inquiry responses and purchase status information from the STTs to the Supervisory Computer. All data should be FSK and Manchester encoded to ensure reliable communications.

One-way addressable converter technology is well established and understood. Communications from the Supervisory Computer to the STTs would be handled within the framework of this technology. Data communications within the system should be half duplex. In this situation, each STT is given a unique address and is polled in a "round robin" fashion. Status and purchase information is returned to the Supervisory Computer from each individual STT immediately after that particular converter is polled by the Supervisory Computer. The upstream communication frequency should be chosen above 20 MHz in order to best utilize the existing MATV system performance.

A suggested band plan is shown in Figure 2.

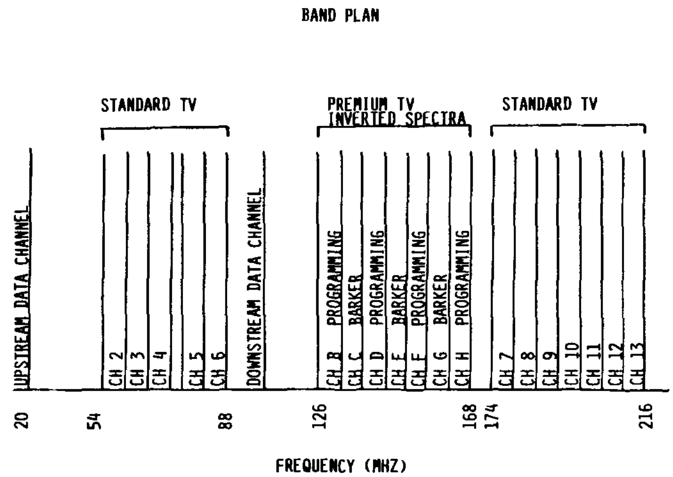

FIGURE 2

IV. SET-TOP TERMINAL

The heart of the IPPV System is the Set-Top Terminal. The STT is the interface to the system that is used by the hotel guest to make purchases of premium entertainment. The terminal must be designed to operate independently of the rest of the system and should report status and purchase information only when polled by the Supervisory Computer.

Extreme care must be taken regarding the mechanical design of any set-top terminal for use in the lodging industry. Hotel guests will be more likely to abuse any piece of electronics that they encounter on a temporary hotel visit than they will electronics that are a part of their own home. Additionally, care must be taken to minimize the possibility of tampering.

The following items should be considered:

1. Spillage of Liquids (Including Beverages)
2. Cleaning with Common Cleansers
3. Shock and Drop Testing
4. Durability of Enclosure
5. Durability of Controls (Buttons)
6. Durability of Labels and Instructions
7. Electrostatic Discharge
8. Lightning and Surge

The set-top terminal should be designed to be transparent to standard (non pay-per-view) programming. Such programming would be carried on the hotel MATV System on channels 2 through 13. The guest would tune this programming using the tuner in the television exactly as if the set-top terminal were not present.

The purchase of a premium program must be easy to make while minimizing the chance for false purchases.

A suggested purchase scenario follows:

To view a premium program the guest tunes the television to channel 3 (or 4 depending on the STT model). The guest then selects the desired premium program by pushing the button on the STT that corresponds to that program. In case of selection of premium programming where there is no charge the STT will tune directly to the desired program. Selection of a pay-per-view program will result in a preview sequence.

The preview sequence allows the viewer the opportunity to decide whether he or she wishes to purchase the program that has been selected. It also acts as a guide as to how to make the purchase.

Immediately upon pushing the button for a pay-per-view program the STT will tune to a "barker" channel. The barker channel will consist of a character generated set of instructions to guide the guest through the purchase.

The STT will then tune to the requested premium channel giving the guest a preview of the program in progress.

At the end of this preview the STT will return to a barker channel (this may be the same channel tuned in the first part of the preview or it may be another barker channel with additional instructions). If no action is taken by the hotel guest the STT will return to standard TV mode. However, if the guest wishes to purchase the program, he or she need only push the button associated with that program a second time before the end of the second barker channel display. When this happens the STT will tune to the premium program and will not default to standard TV until the end of that program.

The purchase scenario is designed to prevent false purchases, as two positive actions are required in order to purchase a program.

The length of the barker channel

displays and previews should be software programmable in order to customize the system to the individual requirements of each installation. These parameters should be downloadable from the Supervisory Computer and remain resident in the STT for operation independent of the Supervisory Computer. Which buttons are pay-per-view and which are free supplemental programming as well as the frequency to be tuned when the buttons are pushed should be downloaded from the Supervisory Computer and be resident in the STT in order to maximize system flexibility. Such parameters should be downloadable globally and by unique terminal address.

It is assumed that the premium programming will not be received without the use of the STT. This makes possible the simplification of the system hardware. The only frequency conversion done by the STT is done on the premium channels. Consequently these channels can be injected into the MATV system with inverted spectrum, permitting the use of a single conversion with high side local oscillator in the STT. Standard TV programming is maintained in its standard format as these channels are tuned by the guest's television directly. The inverted spectrum adds some incremental security to the system since the majority of hotel TVs are limited to channels 2-13 (non-midband). Additionally, the majority of TV's in hotels capable of midband reception are not able to receive inverted spectrum. If necessary a midband trap can also be added.

In order to support the purchase scenario given above, the STT must contain the following seven sections:

1. Microprocessor and digital support circuits
2. Keypad and display
3. RF switch
4. Down converter
5. Data receiver
6. Data transmitter
7. Power supply

A block diagram is shown in Figure 3.

The microprocessor in the STT must control all the functions of the terminal. It must also interpret all the messages received from the Supervisory Computer, implement the address recognition function, and formulate responses for the inquiries from the Supervisory Computer.

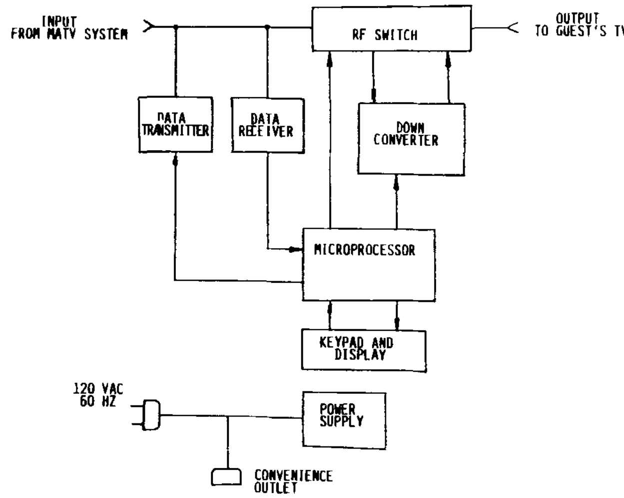

FIGURE 3

The STT should be equipped with a keypad and display. This keypad may be connected directly to the microprocessor and is intended for use by the guest to select premium channels.

The RF diode switch is used to route RF either directly to the guest's TV for standard TV mode or to route the RF to the down converter for premium mode.

The down converter is used to convert premium programming from the VHF midband to the output channel of the STT (3 or 4 depending on the model). The down converter should consist of filtering, a mixer and a phase-locked loop local oscillator.

The filtering in the down converter should be sufficient to insure a passband flatness on the desired output channel of less than 3 dB peak-to-peak while providing attenuation of at least 60 dB at frequencies of +/-12 MHz of the desired picture carrier frequency (<-60dB at the "semi-adjacent" channel picture carrier frequency). This would prevent theft of service by preventing the hotel guest from being able to tune the television to a free premium program and then view a pay-per-view program by tuning the TV to a channel other than the desired output channel of the STT (see Figure 4).

The STT must be equipped with a data receiver to receive commands and inquiries from the Supervisory Computer. The output of the data receiver would be fed directly to the microprocessor for decoding.

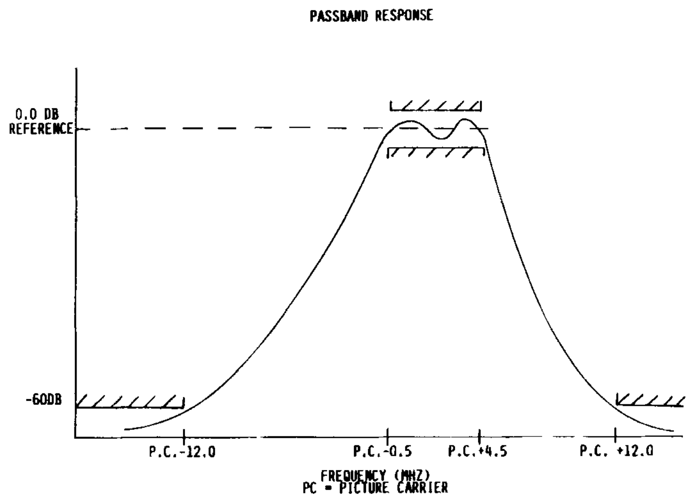

FIGURE 4

In order for the STT to respond to inquiries, report status information and report purchase information, it must have a data transmitter. The circuit could be a simple crystal controlled narrowband FSK transmitter. Output power must be sufficiently high to ensure reliable communications over the lossy upstream data channel while not creating harmonic energy of sufficient amplitude to generate interference in the received television channels.

The transmitter would be normally inactive. It would become active under the control of the microprocessor. A circuit should be incorporated in the data transmitter to prevent system failures that would occur if the transmitter of one STT became active continuously. If this situation were to occur, communications with all the other terminals in the system could break down because the upstream data channel would be occupied continuously. It is suggested that a circuit to prevent this must monitor the time a transmitter has been active and "time out" if the transmitter has been active for more time than is required for normal communications. The circuit must also monitor the length of the delay between subsequent transmissions. If the delay between transmissions becomes too short, the circuit should prevent the transmitter from becoming active. As a consequence of these functions the circuit has been named the "Anti-Babbling" circuit.

The power supply, as the name implies, should provide D.C. power for the other circuits in the STT. A non-switched A.C. convenience outlet should be provided to ensure a location for plugging the television in the guest room.

V. DATA INTERFACE

The Data Interface acts as the main communication interface for the entire system. The device is also used to transfer data, not only between the STTs and supervisory computer but also from the remote control interfaces. Additionally the unit generates baseband composite video signals for use as "barker" channels.

The Data Interface must, as a minimum, perform the following functions:

1. Command Processor
2. Data Transmitter
3. Data Receiver
4. Video Processors

A brief description of each is given below.

The command processor acts as a central controller. It interprets communications between itself and the outside world. It has the task of interpreting commands from the Supervisory Computer and passing appropriate information along.

The data transmitter and data receiver work together to provide data communications between the STTs. The performance must be adequate to overcome the losses in a passive MATV distribution system (approximately 70 dB worst case).

The video processors are used as character generators and generate the composite baseband video used for the "barker" channels. The information for the these screens is downloaded from the Supervisory Computer and can be entered into the Supervisory Computer remotely or locally.

An optional function is the remote control interface. A suggested realization uses 300 baud Bell 103 type data receiver. This receiver can be used in conjunction with any audio channel (such as a phone line, secondary audio channel from a satellite receiver or unused audio channel from a stereo VCR) to operate the system entirely by remote control. All scheduling and configuration commands should be supported through this input.

VI. PREMIUM PROGRAMMING INTERFACE

Premium programming is inserted onto the existing MATV system in the midband on channels B thru H as shown in Figure 2. Up to four channels of premium programming and three "barker" channels can be inserted in this manner.

The sources for premium programming are various. VCR delivery, satellite delivery and cable delivery are all viable alternatives. The only requirement is that the signals are placed on the hotel MATV system with inverted spectra per the accepted Band Plan.

Additionally, the premium programming interface must provide means to modulate the "barker" channel(s) composite video output of the Data Interface. The "barker" channels are also injected on the cable with inverted spectra.

VII. SUPERVISORY COMPUTER

The Supervisory Computer consists of a personal computer executing a Supervisory Computer software package. This software initiates all system communications, controls program scheduling, provides daily bills to the hotel manager and maintains a summary of program purchases. The hardware consists of a P.C., CRT display, printer and optional phone modem. The Supervisory Computer is hard wire connected to the Data Interface.

The Supervisory Computer should have the capacity to be operated in either of two modes; console operation or operation from remote port. Console operation is done locally and is used when the system is to be operated by the hotel manager or staff. Remote operation is done by the phone modem. This mode of operation allows the programming supplier to access the system for configuration or billing information retrieval.

Operation of the Supervisory Computer should be as follows:

Console operation is initiated upon power-up. The Supervisory Computer will display an entry screen on the CRT. Access is password controlled. Individual passwords should be provided to limit the levels of access to the Supervisory Computer.

All console and remote functions are menu driven. The main menu appears after password approval. An internal clock maintains a record of time and date. All functions should be supported in console and remote modes. The Supervisory Computer should have a battery back-up to handle power outages.

Billing information is maintained within the Supervisory Computer. This information can be accessed in several forms. A billing summary can be done on a "by room". Billing information can also be retrieved by program and date in order to facilitate billing of the hotel by the programming supplier.

Inputs required by the Supervisory Computer consist of program time, type, price and title. This information is used to configure terminals for purchases and to properly interpret purchase and status information from the terminals. The information can be entered directly by the operator while in console operation or entered automatically while in remote operation by use of the automatic scheduling interface.

The operator should be capable of implementing special room overrides in order to satisfy special requirements. The STTs can be disabled on a "by room" basis or on a "by program" basis. This feature can be used as a tool for parental discretion. Similarly the STTs can be returned to normal operation using this feature. This feature is required to support cash customers and premium programs that are included in the room fee.

It should be possible to "pre-buy" a program. The operator can authorize a particular STT to receive a program without a preview sequence. The Supervisory Computer can remotely force any STT to tune a particular premium channel or even force it to tune standard TV.

Upon initial power-up the STT's must be configured by the Supervisory Computer in order for proper purchase and preview sequences to take place. The Supervisory Computer should allow the operator to configure the length of a preview as well as the length that the "barker channels" are displayed during the preview sequence. The operator should also limit the number of previews permitted during any particular pay-per-view program. This last feature prevents a guest from simply watching a series of previews rather than purchasing the program. The Supervisory Computer should also have the ability to re-assign channels to the buttons on the STTs.

Several security functions should be implemented in the Supervisory Computer package. The Supervisory Computer should store a list of STTs that do not respond after several consecutive polls.

The Supervisory Computer should also maintain a record of terminals that have experienced power failures. If some minimum number of power failures occur on a particular terminal during any show then the Supervisory Computer should assume that a theft of service is being attempted by a guest that is trying to reset the preview counter in a terminal. Thereafter the regular polling sequence should be interrupted periodically in order to check the status of the unit in question. Reconfiguration would occur almost immediately making theft by this method impossible.

Several testing routines should be implemented for system maintenance and diagnostics.

VIII. PROBLEM AREAS

The system as described above is extremely flexible and can be used effectively in almost all situations requiring delivery of impulse pay-per-view entertainment in a lodging industry environment. However, a few possible problem areas exist that can cause difficulties for a system operator if not dealt with properly.

1. Cable Fed Properties

   As penetration of CATV service is increased it is often seen as a cost effective means to obtain television programming by many hotel/motel operators. Consequently many hotels are directly cable fed. This creates a problem for the operator of a pay-per-view system in that the VHF midband may already be occupied with programming on the CATV system. Additionally there may be high levels of interference at the data channel frequencies. Adequate filtering of the CATV drop must be done in order to obtain proper system operation. Additionally the operator has a responsibility to see that no signals leak out into the CATV system creating interference for the CATV system. Reception of Satellite programming will soon become better controlled due to the advent of Satellite Scrambling. Revenue recovery for programming provided to hotel guests will become a significant issue in the future.

2. One Way Amplifiers

   Hotel/motel MATV distribution systems are typically entirely passive. However in a small number of larger properties there may exist distribution amplifiers. These amplifiers must be two-way in order for proper data communication to take place. Any one-way amplifiers must be upgraded to two-way in order for the the system to operate.

3. Existing System Performance

   Every care has been taken to ensure that this system will operate in almost all MATV systems with a minimum of modification. However, in extreme cases it may be necessary to rebuild a part of the MATV system in order to obtain proper performance.

IX. CONCLUSIONS

The Impulse Pay-Per-View System described here has been designed to best utilize existing resources. Several key factors have been included in the design that are essential to successful system operation.

1. Distributed Intelligence

   Each guest room contains an intelligent set-top terminal that is capable of handling purchases and normal system operation independently. Purchase requests are therefore processed instantly. The terminal need only report status and purchase information when polled by the Supervisory Computer.

2. Band Plan

A Band Plan has been suggested that best utilizes the existing MATV system resources. In most cases it will not be necessary to rebuild any of the existing MATV system to accommodate IPPV. Premium programming is carried in the VHF midband channels B through H.

3. Data Communications

Data communications occur over two data channels; one for downstream communications from the Supervisory Computer to the guest room, and the other for upstream communications from the guest room to the Supervisory Computer. Frequency selection for these channels must consider the performance of typical MATV distribution systems. Additionally, an "Anti-Babbling" function must be implemented in order to minimize the chances of a catastrophic system communication breakdown.

4. Remote Operation

Remote operation should be supported by the system hardware. Remote operation minimizes the training required of the hotel staff. It also facilitates system configuration and billing retrieval by the programming supplier. All functions of the supervisory computer should be supported locally and remotely.

5. Purchase Scenario

The system is transparent to standard programming. Premium programming is purchased through a preview sequence. Two positive actions are required in order to make a purchase.

6. Software Configurability

The system should be designed to allow a maximum number of system operating parameters to be software configurable. This flexibility allows tailoring the system to the requirements of each individual situation.

Hotel/motel impulse pay-per-view is a vast, virtually untapped source of revenue for the CATV System Operator. The guidelines that have been presented in this paper should help the CATV System Operator to make intelligent choices when choosing and operating a hotel/motel system.

CLI TESTS - MORE THAN A REGULATORY NECESSITY

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ABSTRACT

The Federal Communications Commission in its Second Report and Order on Docket 21006 established the requirement of Cumulative Leakage Index (CLI) tests for systems carrying signals in the aviation bands. The implementation date for filing the CLI reports was deferred until July 1,1990 to allow the industry time to fully develop CLI test procedures. A number of MSO's, in addition to the NCTA, are working to develop these procedures. The basic method will provide only sufficient data to meet the CLI requirements while a more sophisticated procedure will provide the operator with details on the levels and locations of significant leakage areas.

The more detailed tests and additional information will change the CLI test from just an FCC requirement to a basic preventative maintenance procedure.

COMPARATIVE STUDY OF ONE-WAY DATA DELIVERY SYSTEMS

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ABSTRACT

One-way data delivery systems have been receiving more focus lately for data communications. One reason for this is that one-way data delivery systems use the same transmission principles that have made television and radio common communications tools which help minimize receiver costs. Also, the number of receivers in the field does not greatly influence the cost of delivering the information. Therefore, having more receivers in the field actually reduces the communications costs per receiver. The recent focus of one-way data communications has been at extending the use of satellite, radio, and television transmissions for data. The capabilities for each of these communication technologies to support data will be investigated.

INTRODUCTION

Nationwide data communication has been very successful over the past few years for private and in some cases public networks. As the cost of nationwide two-way data communications increases at a steady rate, more investigations and activity into one-way data delivery systems have begun. There have already been many successful systems for one-way data delivery using satellite transmissions directly to receive-only satellite antennas (dishes). Recently, more focus has been aimed on the use of the satellite as the national distribution of data but using alternative methods for the local distribution of the one-way data stream.

SATELLITE

Satellite communications is the focal point for all nationwide communication needs. Ample bandwidth is available for multiple uses of each of the transponders on any given satellite. However, there are some limitations and some complex issues regarding the use of C-Band and Ku-Band allocations for data communications. The major issue is dish size (which impacts the installation costs) versus acceptable Bit Error Rates (BERs).

The typical C-Band transponder available bandwidth with most satellite receivers is 27MHz. Much of the bandwidth is used for video but there is room for at least a half-a-dozen narrow band sub-carriers running at 19.2Kbps each. In order to actually use this capability with acceptable BERs requires a fairly large earth station and/or very expensive receivers. Alternatively, when a transponder is used only for data communications, smaller dishes can be used by using a technology called spread-spectrum. Using this technology, more bandwidth is used per bit but the system allows for the implementation of considerably smaller dish sizes. Spread-spectrum allows for approximately 100Kbps of data per transponder while using 2-foot receive-only dishes.

Low power Ku-Band satellites which allow the receiver to use the smaller dishes have significantly reduced the receiver costs but alternatively have problems with reception under adverse weather conditions. High power Ku-Band satellites, however, are expected to overcome some of these stumbling blocks but neither of these satellites are as available as their C-Band counterparts nor have as large of a footprint.

Another stumbling block in direct satellite distribution has been that each receiver must have its own dish. One effective implementation to get around this problem is to translate the received data into the FM band of a cable system and send it down the cable. This has been a very adequate solution for data communications at 19.2Kbps and below but does require the installation of extra hardware at the head end of a cable system. The over-all costs for the distribution and receivers in this configuration is much more reasonable than with individual dishes.

Direct satellite communications however complex is well understood and can provide excellent bit error performance in a very simple national distribution chain.

RADIO

Radio is a good source of data communications primarily because the cost of the receiver is very inexpensive. Pocket radios are commonplace and the technology is well understood. There have been two major reasons why radio has not been a larger player in data communications:

1) There is no good way to tie the local radio stations into a nationwide network.

2) Previous FCC regulations allowed only one 9.6Kbps data channel.

Satellite communications have played a major role in removing the first stumbling block. Many radio stations have installed their own dishes to receive information on a national basis and this trend is expected to continue. The second hurdle was removed when the FCC deregulated the radio stations and allowed more bandwidth to be used for ancillary purposes such as data communications.

Technically, FM Radio Stations have always had a 200KHz wide bandwidth between carriers. This gives the station a baseband bandwidth of 99KHz which was expanded from 75KHz after FCC deregulation. The stereo audio portion of the bandwidth uses up the first 53KHz and allows the remaining 46KHz to be used for ancillary purposes. When the remaining bandwidth is used for data communications, slightly more than 38Kbps is available.

Hardware is beginning to appear in the radio stations to make use of the extra bandwidth for data communications. However, further testing is required to determine the BER using the expanded communication channels and the amount of Forward Error Correction (FEC) that is required. Also, because most of the local radio transmission stations are not manned, local insertion of specialized data is not anticipated.

TELEVISION VBI

Television is definitely an exploited communication medium. It is almost a universal language in itself and already has a national distribution network in-place. The primary reason the use of the television's Vertical Blanking Interval (VBI) has not had more wide-spread use as a data communication medium is because the VBI is very fragile. Less than 4% of the televsion signal can be used for data communication without affecting the normal video. In order to achieve the high data rates that the VBI can transmit, the realized BER is affected. There are essentially two reasons why the VBI is a fragile medium for data communications:

1) The data is tied directly to the video, therefore, when there is a loss of video (i.e., sync) the data is also lost.

2) The data is AM modulated, therefore, it is not immune to impulse noise.

Technology for stripping the data out of the video has improved tremendously over the past few years which has allowed for the improvement of the bit error performance. Unfortunately, the underlying causes for the errors still exist. The solution for making the VBI a viable communication medium has been to insert appropriate FEC codes to recover the data that is lost. By understanding the mechanism for how the data is lost, the FEC codes that have been implemented are beginning to prove that the VBI is a very viable data communications medium.

The VBI consists of approximately 10 lines onto which data can be inserted. The standard instantaneous data rate is 5.7272Mbps. This computes to be an aggregate data rate of 19.2Kbps per line when using both fields. If all 10 lines were to be used for data communications, the effective data rate would be 192Kbps. However, without an appropriate FEC code to permit an acceptable bit error performance, this data is not very useful. Inserting an FEC code and addressing information into the data stream decreases the aggregate data rate approximately 20% to around 15.5Kbps per line. This would still provide almost 155Kbps if all 10 VBI lines were used.

Similar to the radio networks, hardware using the improved FEC coding is beginning to become available. Performance testing is still a major issue because reception is varied across the nation and within different localities. These seem to be minor stumbling blocks because the majority of the receiving stations that have been tested have shown exceptionally low BER. Additionally, the national distribution of the signal is already in place.

The next step in VBI communications is to get more systems on line and more local insertion of specialized data to augment the nationally delivered information. Even without local data insertion, the television's VBI is a viable data communication medium because no costs are involved in the local distribution of the data other than the delivery of the normal video to the subscriber.

CONCLUSION

One-way data communications is going to be more of a growth area over the next few years. This will happen through three different distribution media: satellite, radio, and television. Satellites will be the dominate national distribution medium with radio stations, television broadcast stations, and CATV operators becoming a larger part of the local distribution of one-way data. The technical considerations are better understood for this type of communication and the technology is available. The next major hurdle is to educate the marketplace so that they can make better use of their data information and the resources available to them.

COMPATIBILITY BETWEEN BASEBAND CONVERTERS AND MTS STEREO

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The MTS stereo signal can pass through a baseband converter for input to a stereo television. The composite MTS signal is also available for an internal or external decoder.

MTS uses signal matrixing for compatibility. Left and right channels are summed (L+R) for transmission in the normal 20Hz to 15kHz range. The stereo difference information (L-R) is transmitted on a subcarrier at 31.5 kHz.

The (L-R) signal is dBx companded to reduce noise. There is no companding of the (L+R) signal. As a consequence, stereo separation is optimized only at unity processing gain. There is a fairly wide volume control range over which acceptable separation is maintained, because separation as low as 10 dB yields subjectively pleasing stereo imaging.

Introduction

The advent of Multichannel Television Sound (MTS) has raised many questions for cable operators and equipment manufacturers. One of these questions is whether the MTS format signal will pass through a baseband converter for decoding in a stereo television.

To understand the implications of MTS in the baseband converter, an understanding of three things is necessary:

1. The components of the MTS signal, and the bandwidth required at baseband to pass them

2. The matrix techniques that are used to maintain compatibility with monaural televisions

3. The implications of the use of companding on only one component of the MTS signal

With an understanding of these three items, it becomes apparent that the MTS signal can be passed, but that the use of the volume control in the baseband converter has an effect on stereo separation.

Components of the MTS Signal

The MTS signal is composed of several components, which can best be understood by examining the composite frequency spectrum shown in figure 1.

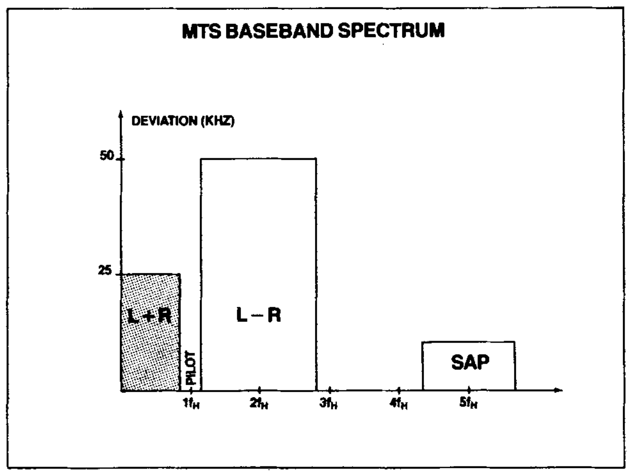


FIGURE 1

The left and right channel source signals are processed in the signal matrixing circuit. Left and right are summed, yielding the (L+R) signal which occupies the 20 Hz to 15 kHz region. This is the frequency range used by monaural television, which receives the proper mix of left and right audio due to the summing.

Immediately above the (L+R) signal, at 15734 Hz (the horizontal line rate, or 1H) is a non-modulated signal called the pilot. This pilot is used in the MTS decoder to generate a signal at 2H.

The right source signal is subtracted from the left source signal (in the matrix circuit of the encoder) yielding a (L-R) signal. This signal occupies the spectrum from 1H to 3H, as a double sideband AM signal on a subcarrier at 2H. Note that the lowest frequency components of the source signal are closest to the 2H subcarrier.

The Secondary Audio Program (SAP) occupies the spectrum between 4H and 6H, centered around a subcarrier at 5H.

The composite signal, including (L+R), (L-R), and SAP (but not including the professional channels) extends from 20 Hz to 88.7 kHz. Any signal path or circuitry used to pass this composite signal must therefore have good amplitude and phase response to at least 90 kHz.

Signal Matrixing for Compatibility

Given a baseband spectrum of 45 kHz, two channels of audio could be transmitted in several ways. One might be to transmit the left channel in the 20 Hz to 1H region, while transmitting the right channel as a modulated subcarrier at 2H (occupying the 1H to 3H region). The disadvantage of this approach would be that monaural televisions would only receive the audio signal below 1H, and would therefore present only the left channel to the listener.

To achieve full compatibility with monaural televisions, the MTS signal uses matrixing. The input signals to the matrix circuit are left and right audio. The sum of these inputs generates one output, called "left plus right" or (L+R). The difference between these inputs generates the other output, called "left minus right" or (L-R). The (L+R) signal contains the information from both channels, providing compatibility with monaural televisions.

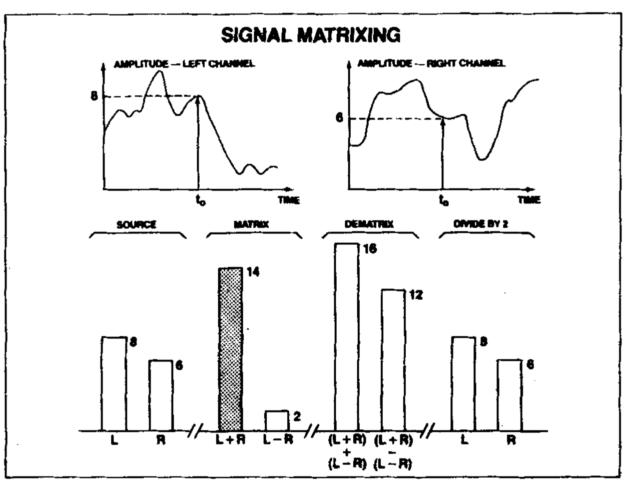


FIGURE 2

An example of matrix signals is shown in figure 2. At time T0, the instantaneous amplitude of the left channel is 8 units. At the same instant in time, the amplitude of the right channel is 6 units. These signal levels are represented graphically under "source". After matrixing, as shown under "matrix", the (L+R) signal is 8+6, or 14 units. The (L-R) signal is of course 2 units. In the dematrix process, the (L+R) signal and the (L-R) signal are both added and subtracted, as shown under "dematrix". The sum signal becomes (L+R)+(L-R), which in this example is 14+2, or 16. The difference signal becomes (L+R)-(L-R), which is 14-2, or 12.

Note that (L+R)+(L-R) equals 2*L+R-R, or simply 2*L. Also note that (L+R)-(L-R) equals L-L+2*R, or 2*R. All that remains to reconstruct the input signals (left, L and right, R) is to divide each output of the dematrix circuit by two.

Signal Companding for Noise Reduction

One common technique for improving the quality of a signal passing through a noisy channel is companding, which is a contraction of "compress" and "expand". The upper left waveform in figure 3 shows a signal without noise as might be input to a transmission channel. The waveform in the top right shows this same waveform after transmission in a noisy channel. Notice that the lowest amplitude portions of the signal fall below the noise "floor", and are masked by the channel noise.

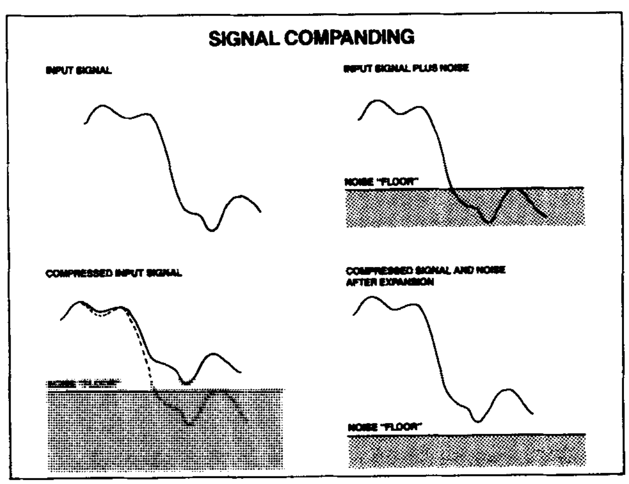


FIGURE 3

The lower left waveform of figure 3 shows the input waveform after compression. The lowest amplitude signals are boosted while the highest amplitude signals are left alone, with a smooth continuum in between. This compression has the beneficial effect of raising the lowest amplitude above the noise floor of the transmission channel.

Unfortunately, it also distorts the original signal, by limiting the dynamic range, or difference between loudest and softest portions of the input source material.

This distortion is corrected, however, in the expansion process, as shown in the lower right of figure 3. The real benefit of the expansion is that the noise floor is pushed lower, beneath the lowest amplitude (softest) portions of the desired signal.

Companding the MTS Signal

Initial tests of the MTS system were done without any companding. It was quickly discovered that several sources of noise degraded the (L-R) channel, such as AM to PM (amplitude modulation to phase modulation) conversion in modulators, transmitters, or television receivers. Because the video signal has strong components at the line rate and harmonics of the line rate, and because this video signal amplitude modulates the picture carrier, any AM to PM conversion in the transmit path will cause phase modulation of the picture carrier at 2H. Essentially all televisions use intercarrier detection of the audio carrier, mixing the picture and sound carriers to generate a 4.5 MHz signal for FM detection. Therefore, any phase modulation of the picture carrier is equivalent to phase modulation of the sound carrier. Thus the incidental, undesired phase modulation produces considerable noise in the audio baseband at all harmonics of the line rate. Recall that the (L-R) information is carried in the composite spectrum around 2H, or exactly centered on the noise from the second harmonic of the line rate. Also recall that the lowest frequency components of the (L-R) signal lie closest to the 2H subcarrier.

The net effect of the MTS spectrum design and the noise generated at 2H was that some form of noise reduction was deemed mandatory. Compatibility issues ruled out the use of any noise reduction on the (L+R) channel, so the dBx noise reduction system was chosen to process only the (L-R) channel.

Impact of Companding Only L-R

Any deviation from unity gain in the path from MTS encoder to decoder causes a reduction in stereo separation. Since the baseband converter can cause a processing gain above or below unity as the volume control setting is changed, it is important to understand the reason for the reduction in separation and its magnitude.

Figure 4 shows a graphical representation

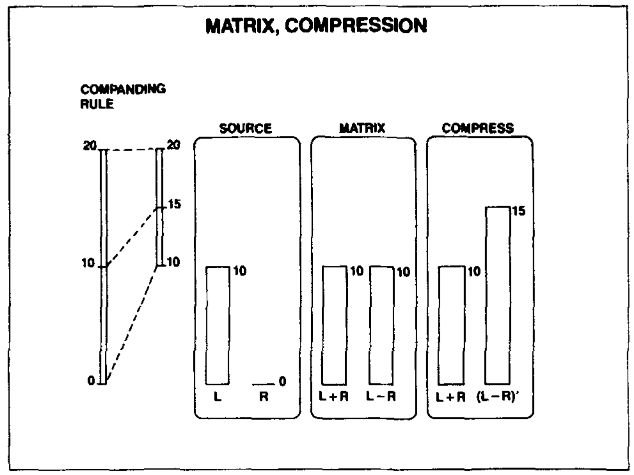


FIGURE 4

of the encoding process. For ease of explanation and understanding of the concept, linear compression of the signal is shown. In fact, logarithmic companding is used in the MTS system.

First examine the "companding rule". Note that in this example an input signal of 10 units is compressed to 15; zero becomes ten; twenty remains twenty. Assume that the source signals are 10 units (left) and 0 (right) - that is, maximum stereo separation. The signals after matrixing are then both 10 units: 10+0=10 (L+R), and 10-0=10 (L-R). Compression then takes place, but only on the (L-R) signal. The L+R signal remains at 10 units, while the compressed (L-R) becomes, in accordance with the companding rule, 15 units. The output of the encoder, then, is 10 and 15 units of (L+R) and (L-R), respectively.

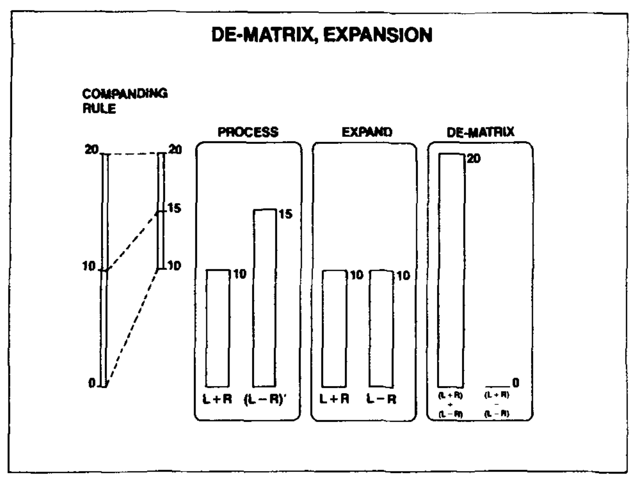


FIGURE 5

Figure 5 shows the decoding of this signal with unity processing gain. In the "process" graph, note that the signal after processing is identical to the encoded signal from figure 4. This processed signal is then expanded, yielding (L+R) and (L-R) both equal to 10 units. On dematrixing, the (L+R)+(L-R) signal (which is twice L) is 20 units. The (L+R)-(L-R) signal (which is twice R) is zero. Perfect separation of the signals has been maintained.

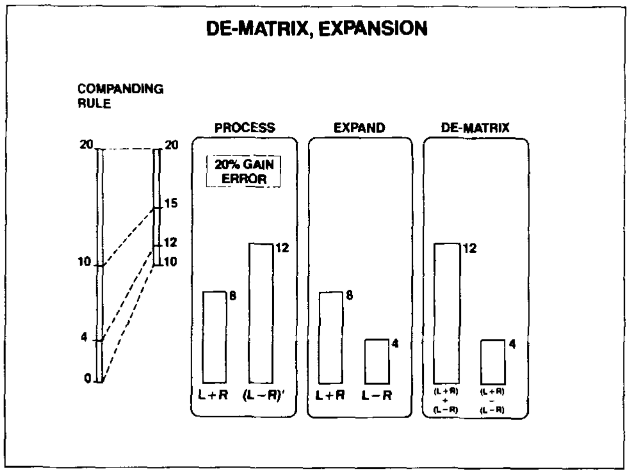


FIGURE 6

Figure 6 shows the effect of non-unity processing gain. In this case a 20% error is introduced in the signal path, so the output levels of the encoder (figure 4) are reduced to 8 units (L+R) and 12 units (L-R). On expansion by the companding rule, the (L+R) signal stays at 8 while the (L-R) signal becomes 4 units. The dematrix circuitry then generates (L+R)+(L-R) of 12 units, and (L+R)-(L-R) of 4 units. The outputs of the dematrix circuit would then be divided by two, yielding 6 units left and 2 units right. Not only is the left channel amplitude incorrect (it started at 10 units), the right channel now has a 2 unit signal (it started at 0 units). This crosstalk from left to right channels is reduction in stereo separation.

Separation Versus Processing Gain

The graph in figure 7 shows, using logarithmic scales, the theoretical separation as processing gain deviates from unity. The separation approaches infinity at exactly unity gain, and falls off to 10 dB at plus or minus 6 dB from unity. The range between these 10 dB points of separation is the usable volume control range of the baseband converter.

Subjective Importance of Separation

To determine the subjective importance of stereo separation, a test was devised where a listener could be presented music with different amounts of separation. Because of the subjective nature of the test, the

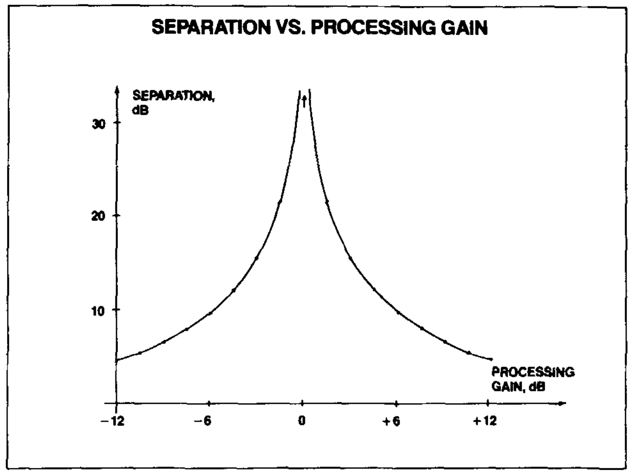
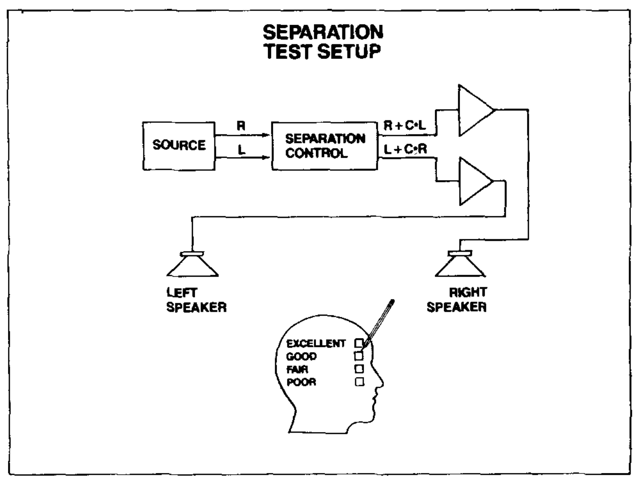


FIGURE 7

subject was simply asked to rate the music as excellent, good, fair or poor. Each participant was initially presented a passsage with no reduction of separation, and was told this. Likewise he was then presented the same passage in monaural and told this. This "best/worst" calibration was repeated, if asked for, anytime during the test.

The same passage of music was then presented at random separation levels, and the subject was asked to rate the acceptability of the stereo image and spaciousness.



Though the results of the test show considerable scatter, as might be expected from such a subjective test, the majority of data points indicate that acceptable separation is perceived at roughly the 10 dB level.

MTS Decoder for Baseband Converter

The baseband converter includes an audio demodulator as well as a video demodulator. This allows the baseband converter to control the volume of the audio signal. An added benefit of this audio demodulator is the availability within the converter of the composite MTS baseband audio signal. This composite signal can be inexpensively decoded in an internal or external MTS decoder circuit. Since a DC signal for electronic volume control is also available in the converter, it can be used to control the volume of the left and right channels in the decoder. Full remote control of volume and mute are thus maintained.

Such a decoder should be welcomed by the consumer who doesn't want to purchase a stereo television, and should generate customer satisfaction and revenue for the cable operator who makes such a decoder available.

Conclusion

Stereo television in the MTS format is an exciting enhancement to the realism of the medium. As more programming is available and the installed base of stereo television increases, the popularity will increase greatly.

The differences between normal television audio and the more complex MTS signal demanded redesign of some sections of the baseband converter, primarily to increase the audio baseband frequency response from 15 kHz to over 90 kHz.

The baseband converter can now pass the MTS signal to stereo television, and can even maintain acceptable volume control and mute capabilities. It can also provide at low cost the composite MTS baseband signal to an internal or external stereo decoder, making stereo television sound available even to those without a stereo television.

CROSSMODULATION - ITS SPECIFICATION AND SIGNIFICANCE

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ABSTRACT

Crossmodulation has historically been one of the basic parameters in the specification of CATV system performance, but it is now considered by many to be an insignificant factor. However, crossmodulation continues to be an issue with CATV operators and there exists some confusion in the industry as to its measurement, and hence as to the correlation of measurements. In general, there is no industry concensus regarding its significance and acceptable levels. This paper discusses its definition and measurement, and describes tests made to correlate measured distortion with observed impairment to a TV picture. The authors concluded the visibility threshold for crossmodulation interference to be approximately -31dB when measured in accordance with the NCTA definition.

INTRODUCTION

Crossmodulation is a familiar term in the CATV industry. Hybrid manufacturers and equipment suppliers specify crossmodulation performance. The Scientific-Atlanta system design group estimates that about half of its customers specify end-of-line crossmodulation performance, yet their experience indicates there is a lack of consistency in the specification and measurement of crossmodulation. More important, there is often a gross overspecification of system requirement due to lack of knowledge of the relationship between the specification and visual disturbance in a TV picture.

The first part of this paper reviews in a general way the specification and measurement of crossmodulation. The latter part discusses results of experiments to relate measured crossmodulation distortion to visibility of interference in a CATV system. A rationale is given to relate the NCTA measurement to a frequency spectrum measurement in an operating system carrying TV programming.

DEFINITION AND MEASUREMENT

Crossmodulation was originally defined by NCTA [1] as:

$$XM(dB) = 20 \log (a/b)$$

where

a = peak-to-peak voltage of the undesired modulation envelope,

b = peak voltage of the unmodulated video carrier.

The basic measurement procedure was also outlined in that document. Accordingly, all carriers except the channel under test are square-wave modulated at 15.75KHz and the amplitude modulation (a) impressed on the cw carrier under test is measured relative to that for a 100% modulated carrier. To achieve high sensitivity for this measurement and discrimination against composite triple beat (CTB) and other noise, crossmodulation is generally measured using a spectrum analyzer or field strength meter to linearly detect the envelope and a selective level meter tuned to 15.75KHz to measure the crossmodulation component. This procedure is still the one in use by hybrid amplifier manufacturers for specifying their devices and by Scientific Atlanta and, to our knowledge, other manufacturers for specifying equipment performance.

The NCTA method measures AM crossmodulation (amplitude modulation of the desired carrier) in agreement with the NCTA definition. However, crossmodulation can also exist as phase crossmodulation due to amplifier phase shifts and non-linearities. Also, at higher frequencies non-linear transistor junction capacities become significant contributors [2]. The development of hybrid amplifiers for 450-550MHz employed a new generation of transistor die that resulted in improved CTB and noise figure performance, but also resulted in less AM-to-PM conversion of crossmod at higher frequencies; the NCTA crossmod specification became worse than for its predecessors. To allay fears of the higher crossmod specification, tests were conducted at Scientific Atlanta with TRW engineers in 1982 with the 5000 series transistor-die hybrids [3]. It was demonstrated that in an HRC phase-locked system and at the lower channels where CTB is a minimum, performance seemed to be limited by CTB, not crossmod. Crossmodulation on channel 2 measured -32dB by the NCTA procedure; the composite triple beat plus second order beat (measured not phase locked) was -42dB, yet when crossmod was eliminated by the by-pass test [4], the visual distortion appeared about the same. This is not too different from results of the test described later.

Crossmodulation is also measured in the frequency domain by measuring the sideband level of the line-frequency (15.75KHz) sidebands. For 100% square-wave modulation the first order sidebands are 10dB below peak (unmodulated) carrier level. Thus, 10dB is added to the first sidebands to obtain the equivalent NCTA measurement. If crossmod exists as both AM and PM, upper and lower sideband levels will be different. In this case, 10dB is added to the average power of the two sidebands (relative to unmodulated carrier power) to obtain total crossmodulation ratio. The AM component can be measured as before; AM and PM crossmod are added on a power basis to obtain total crossmod.

An advantage of the spectrum analysis method is that it can be employed to examine crossmodulation on an operating CATV system (if the carrier for the channel under test can be temporarily unmodulated). Another possible advantage of this method is that in an HRC phase-locked system it will show sidebands (which in effect are the same as crossmod sidebands) due to modulation of carrier beats. The carrier for the channel under test may be turned off for this test eliminating crossmodulation as the source of unwanted sidebands. Crossmodulation by the sideband method is outlined in the Hewlett-Packard "Cable Television Systems Measurement Handbook" [5]. This is also basically the procedure established by Canadian Broadcast Procedure 23 for evaluation and proof of performance of CATV systems [6]. Naturally, results of these measurements will be quite different from those made by the NCTA procedure since it is based on 100% square-wave modulation of all carriers. The next section discusses how these two measurements relate to each other and to visible distortion in a TV picture.

CROSSMODULATION INTERFERENCE TEST

The relationship of crossmodulation distortion and its effects on a TV picture in a high-capacity CATV system are difficult to quantify partly because of the difficulty in isolating crossmodulation from CTB and other distortions. Experiments for this have been devised, however, and the results of one are reported in this section. Figure 1 shows the set-up used to measure the level of crossmodulation for subjective levels of interference to TV pictures or test patterns. In this experiment 28 independent video sources, (including three scrambled channels) modulated a HRC phase-locked headend system. The

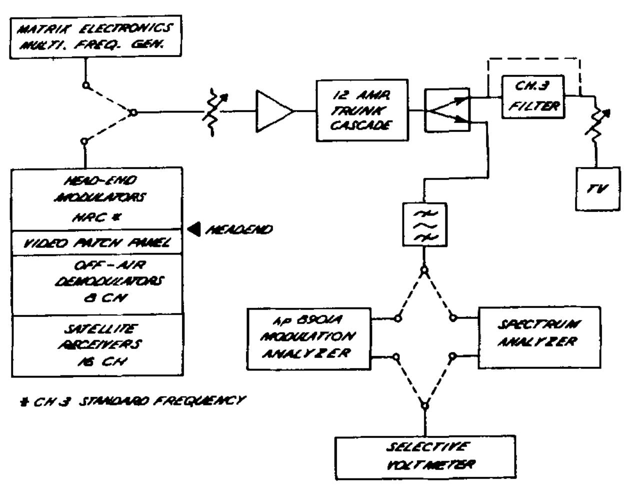

Figure 1. Crossmodulation Test Set-Up

system was loaded to 33Ø MHz; there were 42 channels in all, 14 of which were duplicated. The headend output was connected to a cascade of 12 55ØMHz push-pull hybrid trunk amplifiers. The output of the cascade was viewed on a Mitsubishi TV receiver and the corresponding levels of distortion were measured.

The procedure used to observe crossmodulation without the destructive effects of CTB was to offset the channel being observed, channel 3, to the standard frequency and then to turn off the channel above it. Since for HRC all carrier beats including second-order beats are at multiples of 6 MHz, these beats are at the band edges of channel 3 and thus do not interfere significantly with the signal being observed. At system levels high enough to produce visible crossmodulation, beats between sound carriers and picture carriers became quite significant; therefore all sound carriers were turned off. The spectrum within the video bandwidth was relatively clean. There were some spurious signals, probably due to luminance - chrominance carrier beats, but those were more than 6ØdB below the video carrier. The TV picture was clean except when levels were elevated further to produce high distortion in the picture.

In this experiment TV programs and test patterns were observed and the operating level that produced barely perceptible crossmodulation was determined. Crossmodulation was most noticeable on a flat field approximately 7.5-2Ø IRE, so data was taken for that condition. Results are summarized below:

SYSTEM PERFORMANCE FOR BARELY PERCEPTIBLE CROSSMODULATION.
42 CHANNEL LOADING

SIGNAL LEVEL (dBmv)	CTB (dB)	CROSSMOD (dB)		
		AM	PM	TOTAL
49.5	-39	-31	-4Ø.5	-3Ø.5

Data was measured by driving the cascade from a Matrix multi-carrier generator (standard frequency plan). Crossmodulation was measured with a Hewlett-Packard 89Ø1A Modulation Analyzer calibrated for agreement with the NCTA definition. Crossmodulation was also measured by measuring the 15KHz sideband levels and by using a spectrum analyzer and wave analyzer to measure the AM component as in the NCTA procedure. Results agreed within 1 or 2dB.

Figure 2 is the spectrum that resulted when all channels were 1ØØ% synchronously modulated as in the NCTA procedure; Figure 3 is for the system loaded with TV channels. With video modulation the sidebands varied around -65dB with large fluctuations due to the random nature of the video signals. Figure 3 was recorded with the spectrum analyzer operating in the peak hold mode for 1 minute to capture transients peaks. Recordings made this way were more consistant and easier to compare.

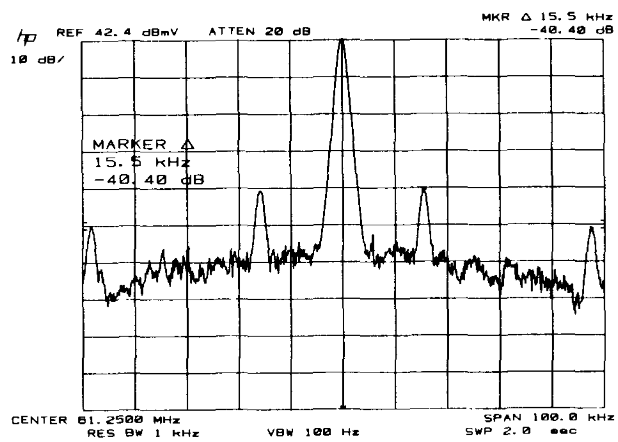

Figure 2. Crossmodulation Spectrum, Square Wave Modulation

As noted, there was a large difference in sideband levels between synchronous square-wave modulation and video modulation - a reduction from -4Ø dB to an average of approximately -65 dB or a peak of about -58 dB. This large reduction is caused by (1) a single TV channel interferes less than if it were 1ØØ% square-wave modulated at or near the line frequency, and (2) TV signals are generally uncorrelated, and uncorrelated signals add on a power

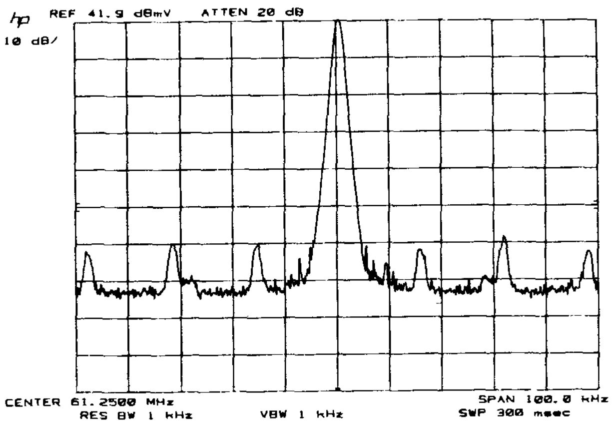

Figure 3. Crossmodulation Spectrum, Video Modulation

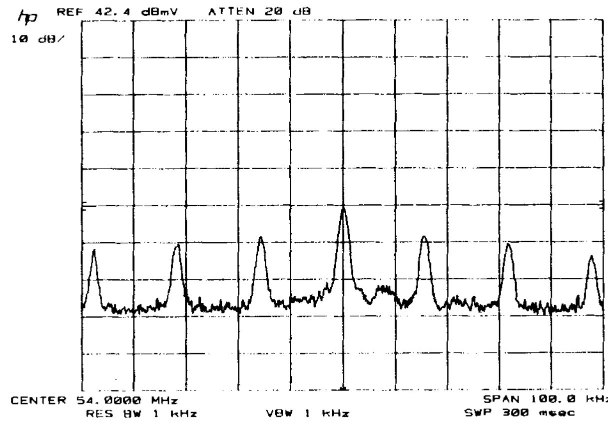

Figure 4. Beat Modulation Spectrum, HRC Phase Locked

basis, whereas for synchronous modulation the crossmodulation components add on a voltage basis. If we assume for simplicity that all carriers are equal amplitude and amplifier distortion is third-order and independent of frequency, synchronous crossmodulation will be proportional to the number of channels. For random TV modulation, crossmodulation will be proportional to the square root of the number of channels. Thus, the difference is proportional to $\sqrt{N}$ (N is the number of interfering channels), which in our case is 42, or 16 dB. This $\sqrt{N}$ relationship was born out in earlier experiments in which crossmodulation was simulated and its effect measured for 1-24 independent program sources. (A review of Figure 3B of [7] shows the departure from $\sqrt{N}$ to be less than about 2dB for 2-24 channels).

In order to correlate results obtained using square wave modulation of a carrier with results obtained with interfering video carriers, it was necessary to correlate the power at the major spectral points of the square wave modulated signal with the corresponding energy in the modulated video signal. Since interference is determined by the square of the amplitude of the interfering carrier, an experiment was devised to compare a squared (baseband) video signal with a squared baseband square wave. In the experiment baseband video and baseband square waves were squared using a four-quadrant multiplier IC and the energy in a 1 KHz bandwidth at line frequency was measured. It was found that the average level of the video signal so processed was 1ØdB below the corresponding level using a square wave. Thus, this factor (1ØdB) plus the 16dB reduction for N form an explanation, although certainly not a rigorous one, for the large difference in sideband level that was experienced with video modulation.

Fig. 4 shows the spectral interference at channel 2 with the carrier off. All other channels are TV modulated (HRC phase locked) and operating levels are the same as before. Non-linear distortion creates carrier beats (CTB, composite second order beats, harmonics, etc.) and these are phasor summed at carrier frequencies with each beat modulated by carriers that produced it. The composite beat has a carrier coherent with the desired video carrier and modulation of the beats produce 15.75 KHz line-frequency sidebands. The result appears the same as crossmodulation except that in this case the sidebands are present without the carrier for the channel under test, and by definition these can not be due to crossmodulation. These sidebands are evident in Figure 4. In Figure 4 as in Figure 3 the recording was made with the spectrum analyzer operating in the peak hold mode for 1 minute. The sidebands are very nearly the same in both cases, suggesting the expected interference would be the same. Actually, there was noticeably a slight difference; interference to channel 2 (beat modulation) was a little more pronounced than the interference observed in channel 3 (crossmodulation)*. Thus, even at the lowest channel where CTB is lowest, beat modulation produces more interference than crossmodulation; CTB will dominate even more at higher channels.

The sideband level reported here we believe to be essentially in agreement with that reported by Paul K Wong [8] and Canadian Broadcast Procedure 23, Issue 2 (BP 23) [6]. Mr. Wong states that crossmodulation will be just visible to most people when the ratio of the first-order sidebands of the interference to the unmodulated carrier is greater than -58dB, and that other established results using defined viewing conditions and a large variety of observers indicated that the threshold can be 3dB worse, i.e. -61dB. BP 23 specifies that qualification of crossmod specifications be conducted by measuring sideband levels at the subscriber terminal. Visibility threshold is given as 58dB below peak video.

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* Because of the random phase of the video carriers, the resulting beat modulation should be equally distributed between AM and PM, and the subjective interference will be less by nearly 3dB than that for AM crossmodulation only. In [7] we concluded phase crossmodulation was less damaging to a TV picture by approximately 9dB.

CONCLUSION

Based on the tests described in this paper it was found that the visibility threshold for crossmodulation is at or near -31dB as measured in accordance with the original NCTA definition. With other system operating environments, viewing conditions, and subjects, results will vary. For CATV system design it may be prudent to allow some margin in specifying crossmodulation distortion, but findings herein indicate that in current useage crossmodulation is considerably over specified.

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DATA INTEGRITY IN ADDRESSABLE CATV SYSTEMS

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ABSTRACT

Addressability dictates successful delivery of control data to paying subscribers and to non-paying customers. The ability to supply or withhold programming services is fundamental to economic viability. Yet this unseen control element is often the least monitored. If it does not perform well revenue can be lost. A good fundamental design and diligent application of monitoring and maintenance are required to attain and retain integrity of the control data channel. Many data monitoring techniques are available depending on the distribution system configuration. Persistent testing and designed-in flexibility allow trouble scenarios to be discovered and countered.

INTRODUCTION

The importance of good integrity of the video and audio signals in the CATV operation is quite evident. They form THE PRODUCT for which the subscriber is willing to pay. In a non-addressable pay system another element enters the picture; the scrambling technique. An addressable system adds a fourth element; the control data. For optimum security the data and scrambling subsystems are integrally related to each other. They serve to control the delivery of the product to the customers.

Scrambling and data are not elements paid for by the subscriber for his gratification. They are there only to serve the operator. Functioning satisfactorily, the customer is at best unaware of their existence. Malfunctions can only be a detriment to his satisfaction by interrupting his paid services. When a malfunction of the data system fails to withhold services from a nonpaying viewer, lost revenue occurs. Customer complaint monitoring serves only as a gross check of performance to paying customer. However viewers receiving free services are unlikely to complain, so additional monitoring measures are required.

TECHNICAL DISCUSSION

The Control Data System

The ability to supply or withhold "the product" upon command is a fundamental requirement of an addressable system. Thus control over the descrambling decoder is the control data system's primary purpose. Interface to a business system for billing purposes and control of pay features and other services are ancillary functions.

In its broadest sense the data system (Fig. 1) consists of the business system controlling a data channel which controls the scrambling system which in turn controls the video and audio to the paying customer. The capability to monitor performance at all points in the system is essential. The ultimate function is the maximization of revenues from satisfied subscribers while minimizing lost revenue through security failures or service interruptions.

Data Distribution

In general an addressable scrambling system has two data channels. The out-of-band channel carries the addressing and control data to configure the decoder to its authorized mode. The in-band data carries channel specific information including tier level and any time-varying scrambling commands. Some systems operate with only one data channel but most likely sacrifice security or data integrity or both in the process.

Figures 2 through 5 show typical data distribution systems where remote operation is required. It is assumed that the out-of-band data is transmitted remotely while the in-band data originates from the specific channel scrambler at the headend site. The "special purpose data" terminology reflects the fact that the data from the controller to the decoder is not typically a standardized format (such as RS-232) but a special format for one-way, asynchronous message transmission over a "noisy" communication path. A Data Repeater is shown which is used as the last line of defense, transmitting "pseudo data" to keep the decoders operating in the event of complete loss of data.

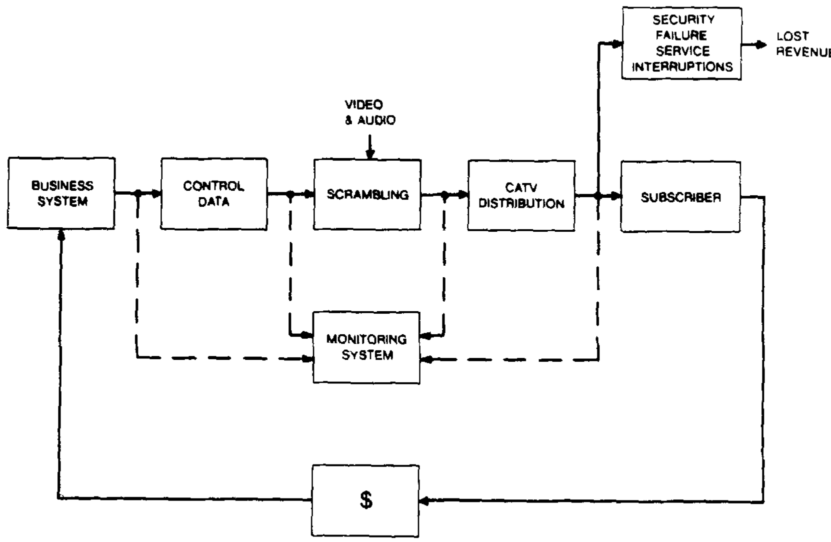

Fig. 1. THE CONTROL DATA SYSTEM

FML. In an FML link system (Fig. 2) baseband video (0-4.2 MHz) is combined with FM subcarrier audio channels (5.6, 6.2, 6.8 ... MHz) and transmitted over a single FML carrier. A reliable interface with this equipment utilizes one audio subcarrier slot (e.g. 5.6 MHz) for data modulated and downconverted to the subcarrier frequency for direct addition to a FML transmitter. At the receive site the subcarrier is then upconverted back to the data carrier frequency (usually in or near the FM band; 88 to 108 MHz). No additional modulation/demodulation is required to utilize the FML and little opportunity exists for developing data errors.

AML. In an AML system (Fig. 3) all channel carriers, FM carriers, and data carriers are transmitted in the exact frequency spectral relationship which they will be carried on the CATV system. The data modulation is done at the Master Headend site so the data carrier is transmitted intact. If the carriers are configured as on the CATV system, no significant degradation should occur over the AML. There is a slight reliability benefit to locating the data repeater at the receive site to guard against failed AML hardware carrying the data. The repeater hardware must then be duplicated at each hub and additional filtering is required.

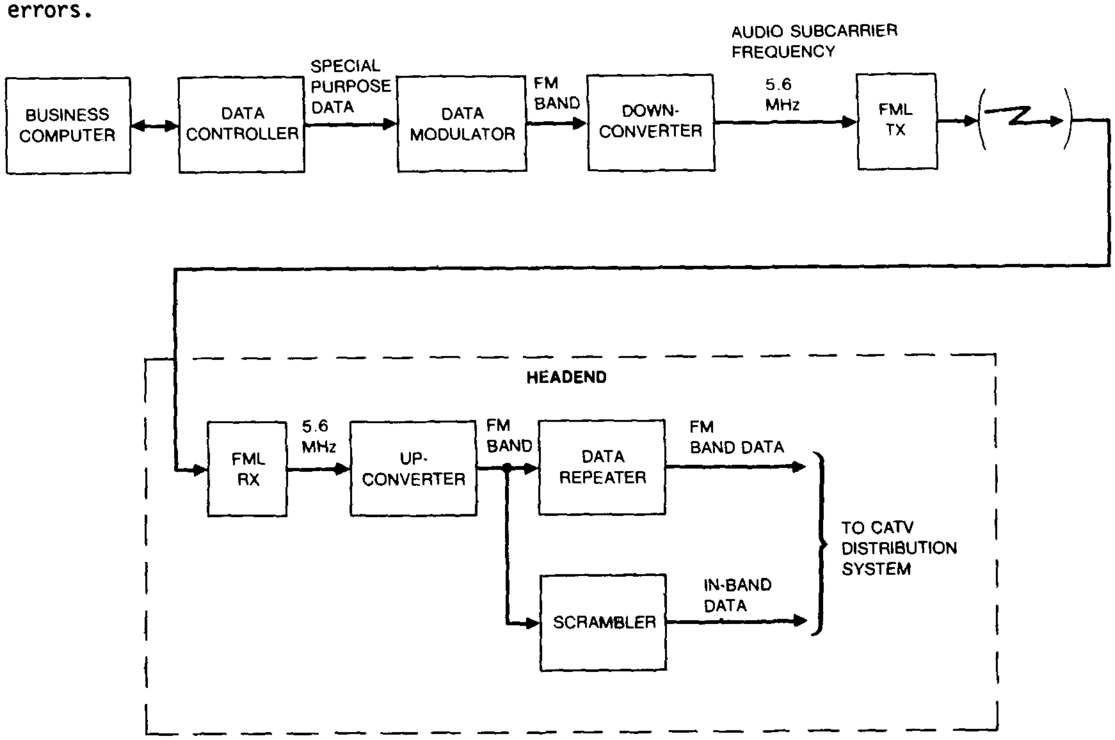

FIG. 2. FML DATA DISTRIBUTION

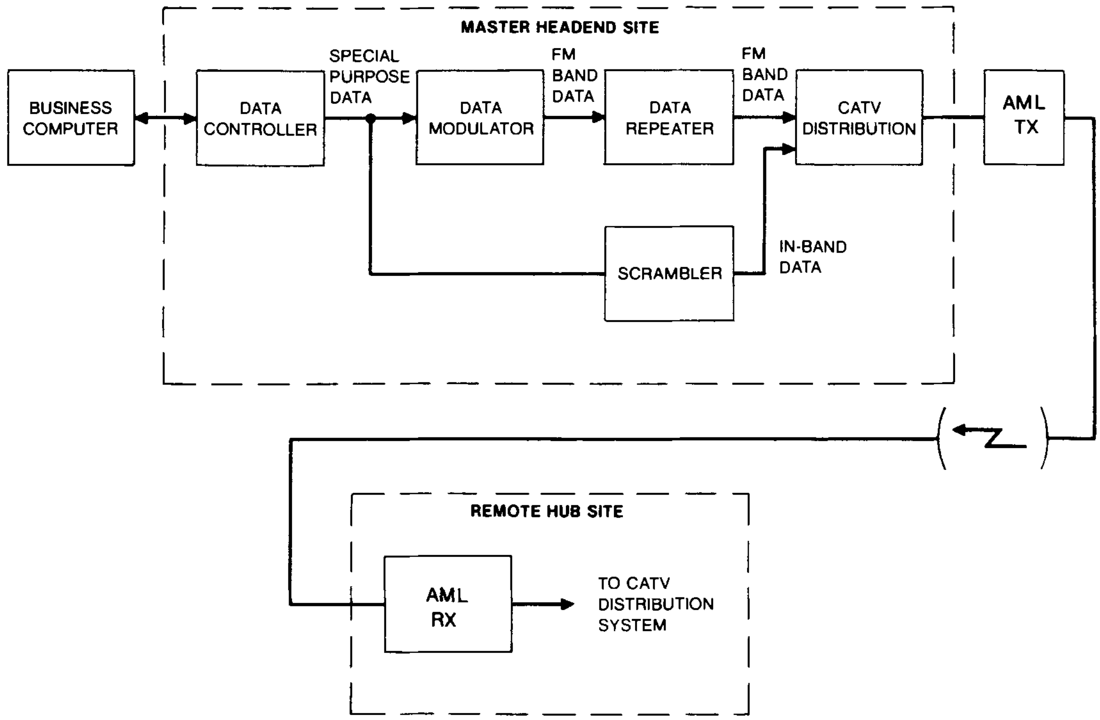

FIG. 3. AML DATA DISTRIBUTION

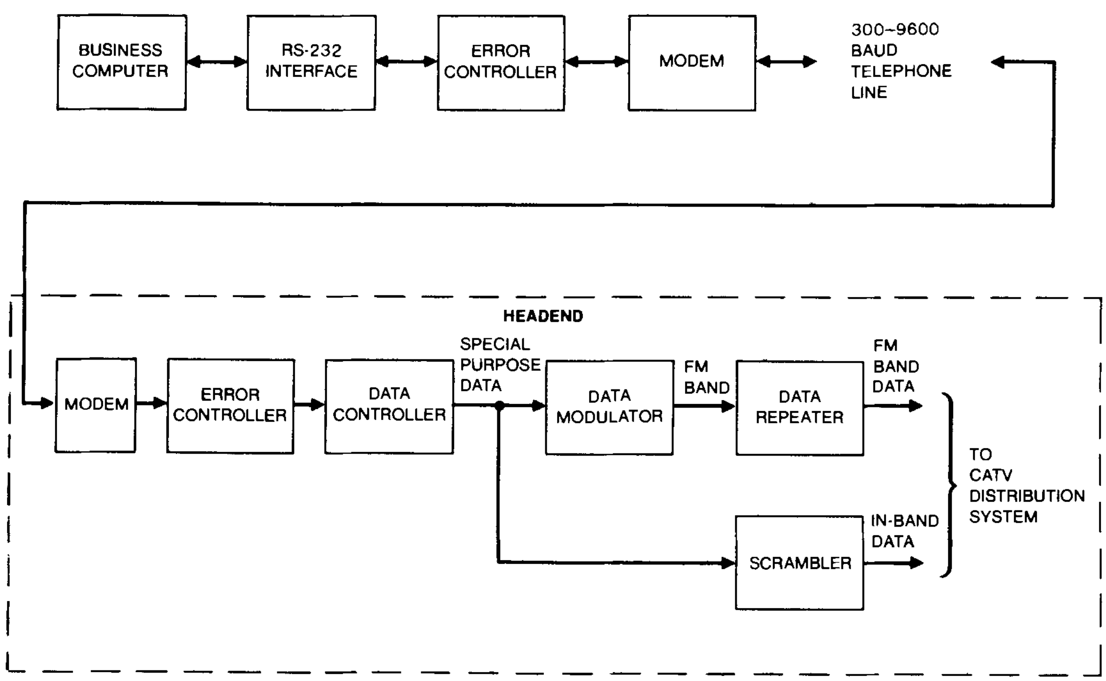

FIG. 4. TELEPHONE DATA DISTRIBUTION

Telephone. The special purpose data for transmission over the cable system is not RS-232 modem compatible as required for distribution via telephone. It is necessary to have a system configuration in which an RS-232 data link can be split. In Figure 4. an additional RS-232 interface is shown and it is assumed that the Data Controller is RS-232 compatible. The main shortcoming of this configuration is the high likelihood of injecting noise via the telephone line. The error controllers are intended to protect the data from noise. The subject of noise will be discussed in more detail below.

Upstream Cable. When the CATV system passes the business office after leaving the headend, it may be possible to use upstream processing (also referred to as subtrunk processing) to accommodate the data carrier (Fig. 6). This approach is similar to the FML case except that the frequency conversion is made compatible to the upstream equipment (below VHF TV channels; 5 - 40 MHz).

Other. In other data distribution systems, such as optical fiber, the specifications of the particular equipment must be matched to the data characteristics to determine the best transmission method. An approach similar to the FML case may be feasible. A video channel may be dedicated to the data signal although special precautions must be observed in regard to clamp circuits.

In many systems the implementation may involve a combination of several of these approaches. For example, the subtrunk scheme may be required from the office to a Master Headend followed by FML to supplemental headends. In this case it may be possible to choose a common conversion frequency to minimize hardware.

Sources of Error and Error Avoidance

Most errors may be categorized as occurring from the following causes:

- o Human Error or Tampering
- o Software Error
- o Hardware Failure
- o Noise or Interference

A distinction must be made between "bit errors" and "message errors." A message is the command that causes the decoder to take action. The digital message is composed of a number of binary "bits." Depending on the design of the individual elements of the system, varying susceptibility to errors may occur. If one of the aforementioned causes of errors results in a bit error, a message error may still be avoided through automatic error detection or error correction.

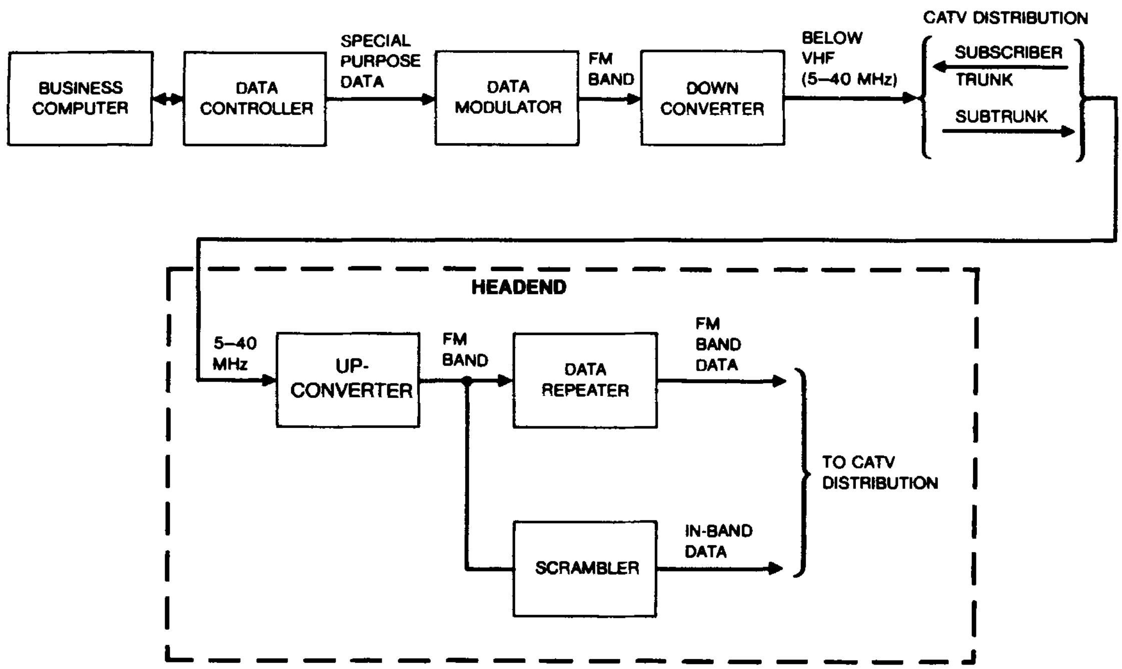

FIG. 5. CATV SUBTRUNK DATA DISTRIBUTION

For example, one of the simplest forms of error processing is to transmit duplicate messages sequentially. With the data receiver designed to respond only if two identical messages recur, most bit error combinations are detected and the bad message is not acted upon. Of course the correct message does not get through either. If the same bit errors occur in each word the process fails to work and a message error would occur.

If three messages are transmitted sequentially and the receiver requires two out of the three to be identical, some bit errors may occur and the correct message could still get through. Modern data communication design techniques allow much more efficient and powerful error detection and correction procedures. However these two examples illustrate the general principle.

The "special purpose data" in Figures 2 - 5 is presumably designed for error detection and/or correction since it must be transmitted over a noisy, interference prone CATV distribution network. It, therefore, is a good candidate for transmission to remote sites. This data however is not formatted for easy interface to standardized equipment and typically has a bandwidth requirement beyond audio circuitry specifications. In the FML, AML, and upstream CATV applications (Figures 2, 3, and 5) the data is sent as a modulated carrier.

In the telephone system case (Figure 4) sending a carrier or the special data format is not possible, so developing standardized RS-232 data is required. From a purely technical point of view, using a telephone line is the least desirable approach for transmission of the addressable control data. Besides slowing the communication speed, a new vulnerability to noise is interjected into the system. But unless a microwave link or alternate communication link exists for other purposes, it is probably not economically justifiable to provide one to handle data only. Thus unless an extremely good communication design has been done within the control data subsystem, external error processing is required. Figure 4 shows the addition of error controllers for error processing of the RS-232 data stream.

In addition to optimizing the system design and configuration, maintenance of all equipment involved in the data system must be diligently performed. The objective must go beyond repair of catastrophic failures to maintain calibration within specification to avoid introduction of errors.

The third area for error avoidance is monitoring, including: hardware functions, software routines, and persistent testing. Monitoring is the means by which data problems become evident and forms the cross-check on inadequacies in design and maintenance.

Monitoring Methodology

Monitor methodology means any effort taken, either hardware, software, or procedural, to detect and isolate problems within the data system.

Software. Monitoring for human errors, tampering, and software errors is a nebulous topic to discuss in a general sense. It entails the integral workings of the business and control software and the scrambling system. The designers must be mindful of these eventualities and build in checks to guard against them. The latter discussion of testing is relevant as a means of detecting loopholes in the system. A printer logging capability of all messages sent to decoders is useful but requires tedious perusal of data. The ability to select a subset of conditions under which the printer logging occurs is an extremely valuable way to trap a suspected occurrence. Running global addressing cycles including a negative global is a means of correcting certain errors that may occur. A global cycle sends the current authorization state to every decoder including those that should be deauthorized. It occurs at random times to thwart efforts to defeat it by disconnecting the decoder at a prescribed time.

Hardware. On the hardware side there are devices and techniques which should be used to isolate and correct errors:

- Monitor Decoder with Oscilloscope;
- RS-232 Data Scope;
- Data Message Analyzer;
- Spectrum Analyzer for Data Carrier;
- Bit and Message Error Rate Testing.

One of the simplest monitor aids is a standard decoder modified to allow the out-of-band and inband data signals to be displayed on an oscilloscope. While not a monitor of message intelligence, it does allow quick and easy perception of gross noise, interference, or carrier degradations and loss of data. This technique should be implemented at the control computer center and each headend site.

An RS-232 data scope is a standard instrument to monitor the messages passing between computers or other hardware devices. It should be online to monitor transactions and made available for troubleshooting other areas of the system as needed. It is particularly important in a system operating remotely via telephone modems.

A Data Message Analyzer is a special purpose device, typically designed by the scrambling system manufacturer, to capture and display the messages in the special purpose data format sent to decoders via the control data channel. if the message structure includes global commands to communicate with all decoders simultaneously, the analyzer should capture them continuously. For other decoder-specific commands the operator selects an address of a decoder that he wishes to investigate. When that decoder is hit with data the analyzer traps and displays it.

The data analyzer for OAK's SIGMA system is implemented with a data demodulator and special purpose data processor driving a smart terminal. It may be utilized at any point in the system where it can be supplied by the data carrier. Figure 6 shows the terminal display of the counts of global commands on the top two sections and the count of individual decoder information in the third section. The bottom section of the screen allows selection of the message content of any of the above message types. This powerful analytical tool is most useful for verifying complete end-to-end system performance including software functions. Since it processes data with the same error routines as the decoder it is a valid indicator of real message errors.

A data analyzer for in-band data has less value for analyzing system problems. Since the in-band data is channel specific and is generated in the scrambler, an in-band analyzer checks only from the scrambler forward. It is usually sufficient to use an oscilloscope or spectrum analyzer for these types of problems.

A spectrum analyzer is an indispensable tool for calibrating, monitoring, and troubleshooting the RF portions of the system. It is used to set and maintain the data carrier amplitude to specified limits, verify proper data modulation, and identify sources of noise and interference.

Bit error rate (BER) testing is the most precise way to monitor the overall system for data performance in the presence of noise. Message error rates may be measured by the same technique. Figure 7 shows the simplest interpretation of the bit or message error rate detector. Known "clean" data is delayed and compared with actual system data. Any differences on a bit-to-bit or message basis are attributable to noise in the system. All systems will have some bit errors. A particular system bit error counter may show 6 bit errors in a one minute time period or 0.1 errors per second. If the data transmission rate is 10,000 bit per second there is 1 error for every 100,000 bits. The BER is expressed as:

$$1 \times 10^{-5}$$

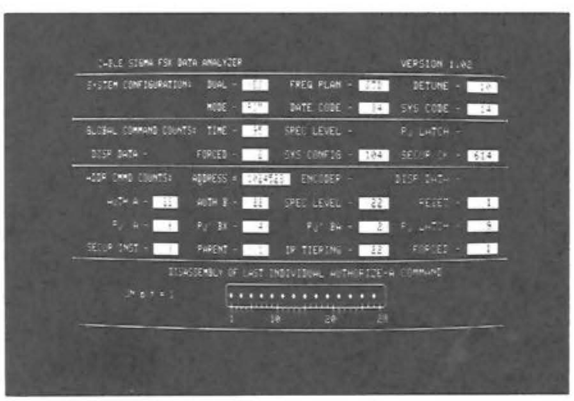

FIG. 6. OAK SIGMA DATA MESSAGE ANALYZER

The data processor in Figure 7 must be the same as the bit or message processor in the decoder with all of its automatic error detection and correction to allow the most accurate representation of the actual system performance. While message error rate testing gives the best picture of system problems resulting in communication errors, bit error rate testing is the most precise measure of threshold noise problems. As with the data analyzer, error rate test equipment is special purpose equipment supplied by the system manufacturer. BER testing should be done periodically to check for subtle system degradations. Or even more preferable, implement a message error detector as a warning indicator to be on-line and running continuously. If a predetermined number of message errors occur in a specified time period, an alarm occurs to warn of a new source of interference or other degradation.

Monitoring Procedures. There are many monitoring procedures which should be part of the CATV operation's normal routine. Customer service monitoring is an important source of information but, as discussed earlier, not sufficient to catch all trouble scenarios. The additional procedures suggested involve conducting tests on a frequent basis to attempt to seek-out suspected or hypothesized problems. Ideas for trial testing can come from creative thinking, "grapevine" information, or real-time tests with employees in their homes. Information regarding system defeat mechanisms can to be gained through the grapevine. Installation and repair technicians usually know the techniques to defeat the system through personal contacts outside of the company.

A continual real-time field test with employees could uncover failure modes resulting in free services to customers. In order for this to be effective the number of homes involved must be significant without being unwieldy (probably 20 to 30 is the right size). Though motivated to participate and provide information through the incentive of free service, the billing functions must be left as though the employee is a paying customer. The actual bill can be cleared later. As many combinations of services as possible should be covered to simulate the real customer base. Since some installations will get more services than others periodic rotations should occur; also exercising the addressability functions more regularly. Disconnect scenarios should also be checked (the employee may be provided with an additional authorized decoder during this period).

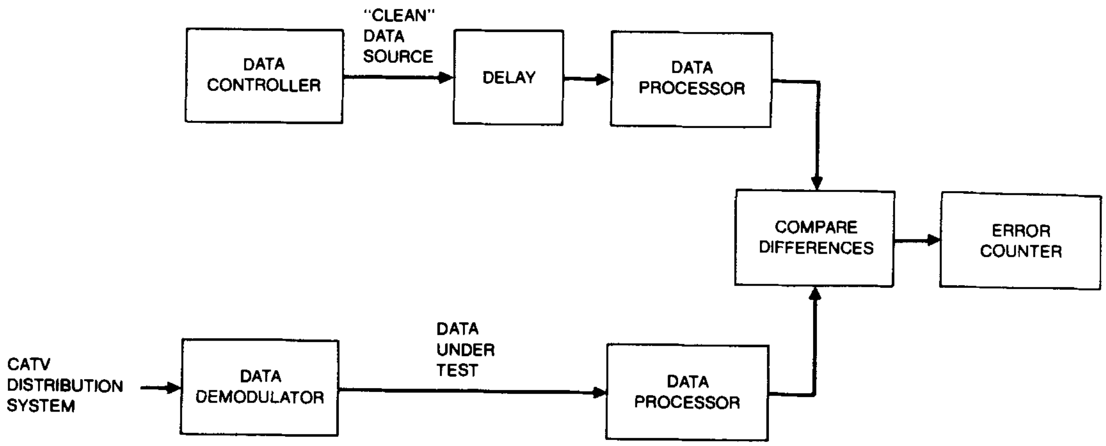

FIG. 7. BIT OR MESSAGE ERROR ANALYZER

CONCLUSION

Equipped with a thorough knowledge of the data system, a motivation to avoid lost revenue, and the resource allocation for requisite monitor systems the CATV operation can do much to avoid loses as the results of data system malfunctions. Even with the best system and software designs it is highly improbable that all prospective trouble scenarios can be anticipated and avoided in the initial design. However the fact that changes in the system are inevitable can be anticipated and flexibility for that change can be designed in.

The addressable system is immensely more complex to design and to operate than a non-addressable one. The factors resulting in maximum profits are more elusive and dictate more applied creativity to optimize; although the potential for profit is higher. It is only through the combined efforts of two partners, the manufacturer and the operator, that full realization can be achieved. The manufacturer must provide a good system design including monitoring capability, good documentation and training, and support of the operation of the system in the field. The operation must apply the system within its design limits, utilize the training and monitoring methodology, be creative and diligent in actively seeking problems and solutions, and commit the resources to accomplish these ends.

DATA MONITOR

Richard G. Merrell

ZENITH ELECTRONICS CORPORATION

ABSTRACT

When a decoder does not function after it is installed, the problem may be the insertion of the data into the global cycle, the software, the encoder, or the distribution system. The decoder itself may be faulty, despite what testing indicates. Finding the problem can be difficult; it is made easier with test equipment, such as a data monitor. The data monitor deciphers incoming data and provides a readout. This includes general and box-specific data. By keying in an address, the operator can determine the authorization for the box with that address. The unit can flag changes in authorization and indicate which bits were changed. It can determine the length of the global cycle and count down the expected time until it is next addressed. It indicates whether there is a market number matches and whether it is authorized to decode. It flags parity errors. It also provides information about the signal itself, such as modulation depth, signal strength, absence of video, sync suppression level, and video inversion status.

THE NEED

It can be very frustrating when a decoder, once installed, does not function properly. Even more frustrating, in many cases, is the attempt to pinpoint the source of the problem. Potential sources are numerous. The data for the box may have been incorrectly inserted into the global data base. There may be a problem with computer hardware or software. Encoding hardware sometimes breaks down or drifts out of alignment. The distribution system is rarely perfect. There will always be some percentage of decoders that will pass factory and incoming inspection tests and still fail in the home.

Any instrument that will help the operator and his equipment supplier localize the problem is very useful. One such instrument is a data monitor. This is an instrument that receives, decodes and displays various data.

Two types of data are of concern: general data and box-specific data. General data are meant for every decoder in the system. Included are:

- o Tier or tag level for the channel tuned, if a premium channel.
- o System market code.
- o Shift in data position, if used to indicate audio scrambling, stereo, type of scrambling, etc.
- o Scrambling parameters, such as video inversion.

The data monitor is designed to emulate the data reception of a normal decoder. The operator can key in the market and address numbers that would reside in a PROM in a decoder. With this capability, the unit can receive and decode box-specific data meant only for it. These data include:

- o Box address.
- o Authorization

Data-related items that can be useful include:

- o Presence or absnece of data.
- o Failures of error-detection bits.
- o Pauses in the global cycle.
- o Length of the global cycle.

General information about the signals can also be very valuable. Although not specifically related to data content, certain parameters have a definite effect on the recoverability of data. Among them:

- o Signal strength.
- o Modulation depth.
- o Sync suppression level.

GENERAL CIRCUIT ORGANIZATION

The general organization of the data monitor circuits is illustrated in Figure 1.

Two RF inputs on A and B cables are applied to an RF switch. Under control of a microcomputer in the tuner control, the switch selects an input and feeds it to the tuner. The tuner includes a voltage-controlled-oscillator; the tuning voltage is derived from the filtered output from the tuner control microcomputer. The tuner output is demodulated and the baseband signal is applied to a data receptor board. Data, contained in the vertical blanking interval, are stripped from the signal and fed in bytes to an 8051 microcomputer. The microcomputer accepts keypad entries and drives seven digits of 7-segment display for alphanumeric indication of address, tier level, etc.; it also drives the authorization and decoder and encoder status displays. The 8051 microcomputer determines when channel changes have been requested through the keypad entries and sends appropriate commands to the tuner control microcomputer to effect the changes. Channel number display is controlled by the tuner control microcomputer. Bargraph displays that do not involve data (signal strength, depth of modulation and sync suppression level) are driven by signal sampling circuits. The baseband output, possibly scrambled, is buffered as video out. An alternate-field data trigger is developed for convenience of analysis with an oscilloscope.

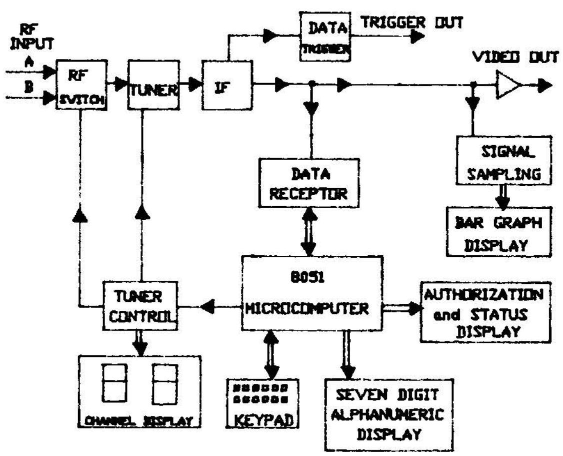

Figure 1 Data Monitor Organization

OPERATION

A data monitor in use is shown in Figure 2. The keys, displays and input and output ports are seen here.

The tuner is controlled through the Channel Up, Channel Down, Enter, Favorite Channel (FC), Clear Entry (CE), A/B select, and 0-9 keys. A channel is accessed by keying in the channel number, then Enter, or by channel scan. If the operator wishes to monitor a small number of channels on a regular basis, the FC and CE keys are used to program those channels as favorite. A scan operation then results in stopping only on those programmed channels. The tuning microcomputer tunes the new channel and drives the channel number and A/B display. In our example, the unit is tuned to Channel 10.

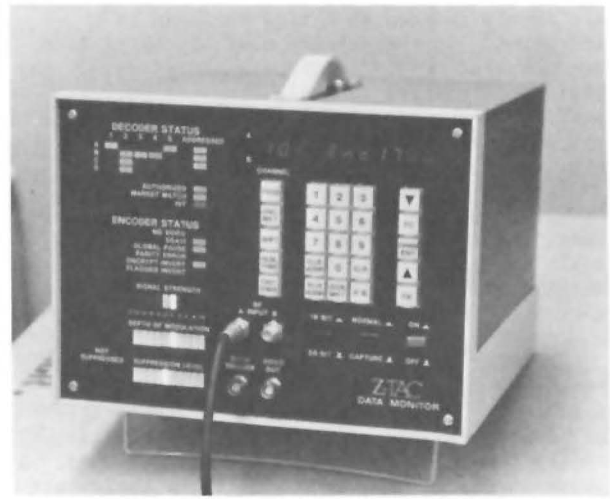

Figure 2 Data Monitor in Operation

Other keys allow the user to select the data to be shown in the seven-digit display. The display shows data keyed in from the front panel, such as decoder address and decoder market code. The Decoder Address and Market Code keys also serve to allow the operator to change those numbers through entry from the numeric keys. The display can also show data derived from the incoming signal, including encoder market code as shown in Figure 2, tier level, and lines of data shift, if data shifting is used as an indicator.

The unit measures the time between successive data transmissions for its address and displays the time as global time. Knowing the length of the global, it counts down the time until the expected time when it will next be addressed; this is displayed as countdown.

The Clear switch clears the seven-digit display and the authorization memory. The Clear Address switch turns off the Addressed indicators. The remaining switches are the power switch, a switch for selecting 18 or 20-bit addressing mode, and a switch permitting selection of normal and capture modes.

When the unit detects data sent to the address that had been specified, it stores the data in an authorization memory organized as four words (A-D) of five bits (1-5) each. These are displayed on 20 LED's in the Decoder Status area. In our figure, the box is authorized for A-1, A-5, B-2, B-3, B-4, C-2, and D-2. Receipt of data meant for this box also lights the hit LED for 1/2 second and lights the addressed LED ('s) corresponding to the words that were received. The Addressed LED corresponding to the last word received flashes. The others, if lit, are steady. For a word that has not been written since the Clear Address key was pushed, the LED is off.

In the normal mode, the authorization data are merely updated each time the unit is addressed. In the capture mode, incoming data are compared to the previously-stored data. Any difference results in a flashing LED corresponding to the bit that is different. The on/off duty cycle indicates the present value of the bit.

Other Decoder Status indicators are Authorized, which tells whether the decoder is authorized for the incoming channel, and Market Match, which tells whether encoder and decoder market codes are the same.

Encoder Status indicators give information about the incoming signal. Video dropout is detected by loss of vertical sync and is signalled by a No Video LED. Existence of data, indicative of a premium channel is displayed. A pause in the global, detected if the parity bit doesn't change for a considerable length of time, is also indicated. The Parity Error LED lights for 1/2 second when the parity bit is incorrect. The Invert LED's tell whether the signal is indicated to be inverted or not.

The IF AGC Voltage drives the Signal Strength bar graph. The bargraph is comprised of ten LED's and is connected so that, normally, one LED is lighted. Internal adjustments allow the bar graph to be linearized and calibrated. In Figure 2, the incoming signal is about -1 dbmv.

Similar circuits drive the Depth of Modulation bargraph. This, too, normally has one lighted LED. The two green indicators in the center, when either is lit, show the modulation depth to be within acceptable limits. A Suppression Level bar graph, also connected so that only one LED is normally lighted, verifies that sync suppression is at the proper level. A Not Suppressed LED lights when sync is not suppressed. In Figure 2, depth of modulation and suppression level are both within acceptable limits.

USAGE

With familiarity, the operator will invent many useful ways to employ this instrument. Some of these might be the following:

If the Parity Error LED flashes, it probably indicates degraded data reception, possibly because of low signal. The Signal Strength indicator and the Market Match indicators would be useful in making this determination.

An inordinately long global cycle or global pause could indicate computer problems. Changes in the authorization data, with the unit in the capture mode, could also indicate computer error.

If a decoder refuses to work properly, even when all the indicators suggest that it should, one should tend to distrust the decoder.

CONCLUSION

The unit described in this paper is clearly dedicated for baseband systems from a specific supplier. The general approach and most of the parameters monitored would be pertinent for other baseband systems and for RF systems as well. The main difference would be in the circuitry and software used to extract the various bits of information.

With normal factory constraints (i.e. low cost, few adjustments, minimal alignment time) removed for data monitors, it should not be difficult for all hardware suppliers to provide this invaluable diagnostic tool for their customers.

DEVELOPMENT OF BASEBAND DECODER COMPATIBLE WITH EIA INTERFACE STANDARD FOR CABLE RECEIVERS AND DECODERS

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ABSTRACT

The EIA Television Receiver Committee has been developing an interface standard for improving the compatibility of TV receivers and decoders operating on cable TV systems. This paper reviews pertinent specifications of the standard and efforts involved in developing a compatible decoder. Specific problems encountered, such as the generation of AGC control signals (derived from received scrambled signals) with the required response time, are described. Overall characteristics of the decoder and its performance during field tests are reviewed.

INTRODUCTION

Separate developments in the cable television and television receiver industries have resulted in equipment with several incompatibilities and duplicate functions, frustrating to the subscriber and cause for non-essential in-home equipment costs. This situation is apparent even with the introduction of "cable ready" television receivers. Subscribers have been finding that after paying additional money to obtain a "cable ready" receiver they still cannot receive channels which have been scrambled.

A committee formed under the EIA (Electronics Industries Association), called the Television Receiver Committee (R-4) Interface Working Group, has been working with cable operators and equipment suppliers to alleviate some of these incompatibilities. The result has been the development of the NTSC Television Receiver Baseband (Audio/Video) Interface Standard IS-15 (reference 1).

This paper illustrates some of the duplicate functions which are eliminated by the use of equipment compatible with the Interface Standard. It also describes some of the steps involved and the problems encountered in developing a cable decoder compatible with the IS-15 Standard.

TECHNICAL DISCUSSION

Cable Versus Broadcast TV Channel Assignments

The utilization and assignment of carrier frequencies different than those assigned for standard broadcast television transmission occurred early in the development of cable television. This provided several advantages, among them the use of frequency bands not available for transmission over the air. This in turn permitted transmission of up to 54 channels without having to use carrier frequencies above 408 megahertz, a definite advantage when considering the increased attenuation of coaxial cables at higher frequencies.

However, until just the last few years, television receivers were unable to tune most of the cable channels available, and required a separate cable converter in order to receive the cable channels. Even today, most television receivers on cable systems are tuned to one channel (3 or 4) and selection of the cable channels is performed with a set-top converter or converter/-decoder.

Television receivers advertised as "cable ready" are now available which can tune the cable channels. But the use of scrambling techniques on some channels means that those channels remain unavailable to these receivers. Furthermore, the use of a converter/decoder to view the programs on the scrambled channels relegates these receivers to fixed tuning on one channel and as a result most of this tuning capability ends up wasted (along with the TV remote control function).

Cable Decoder and TV Receiver Functions

Figure 1 is a block diagram illustrating typical functions performed by a cable decoder and television receiver when interconnected for reception from a cable TV system. In the case of the decoder, the functions illustrated are for an OAK Sigma unit, as this was the unit later modified for compatibility with the EIA standard. The Sigma system's implementation of digital audio transmissions has been described in a previous NCTA paper (reference 2).

The functions of the decoder can be summarized as follows:

a) A remote control unit (or local keyboard) is used to select the channel to be received from the cable by the tuner on the decoder.

b) The output of the tuner passes through the IF amplifier section where filters are used to separate the audio (in unscrambled mode) and video carriers.

c) An audio demodulator recovers the baseband audio signal from the audio carrier (in the unscrambled mode).

d) The video demodulator recovers the baseband video signal from the video carrier. In the scrambled mode, digital signals carrying the audio information are also recovered by this demodulator.

e) If the baseband video signal is scrambled a video unscrambler section provides unscrambling. This section is transparent to nonscrambled signals.

f) In the scrambled mode the baseband audio signals are recovered by the digital audio decrypter and D/A (digital to analog) converter from the encrypted digital signals carrying the audio.

g) An RF modulator section generates modulated carriers on one channel for transmission of the recovered video and audio signals to an external receiver.

The functions of the television receiver are summarized as follows:

a) The remote control unit or front panel controls are used to select the channel to be received from the cable decoder. Note: In most installations, once this selection is performed, the receiver remains on that channel indefinitely.

b) The output of the tuner passes through the IF amplifier section where filters are used to separate the audio and video carriers.

c) An audio demodulator recovers the baseband audio signals from the audio carrier. These signals are then amplified by a power amplifier and used to drive a loudspeaker.

d) A video demodulator recovers the baseband video signal from the video carrier.

e) Sync processing circuits separate the horizontal and vertical sync from the composite video signals. The sync signals are used to drive a high voltage power supply and deflection system which ultimately cause the display of an illuminated raster on the picture tube.

f) Luminance and chrominance processing circuits provide three video signals (one for each primary color) for driving the picture tube thereby displaying a composite color (or black and white) picture.

Figure 1 and the description of receiver and decoder functions above, clearly illustrate that the remote control unit, associated infra-red receiver, tuner, IF amplifier, audio and video demodulator functions are repeated in each unit. These functions impose penalities in complexity, cost and functionality.

In addition the desirability of avoiding repetition of RF and baseband processing, especially demodulation and remodulation, is well established. These processes can introduce distortions into the original signals so that the quality of the displayed picture and audio signals may degrade from repeated processing. It should be noted that decoder manufacturers, being aware of this problem, use considerable care and optimize equipment design to assure that the degradation will be minimum and usually imperceptible compared to direct viewing and listening with a just a receiver.

TV Monitor Approach for Reducing Redundancy

Figure 2 illustrates one approach towards reducing the redundant functions previously described for the decoder and receiver. The approach utilizes a decoder wherein the RF modulator has been replaced by baseband audio and video driver amplifiers. These amplifiers deliver baseband signals directly to a television monitor instead of a receiver.

There are several technical reasons favoring this approach. The interface between the decoder and monitor is very straightforward. Furthermore, a television monitor can display a better picture than an equivalent quality receiver, again because of reduced signal processing. This improved display capability is often exploited in monitors used for computer graphic displays. A monitor can also improve the playback from a video tape recorder or other video source which features baseband video output.

However, this approach was not seriously considered by the EIA committee since most cable television subscribers already own receivers, not television monitors.

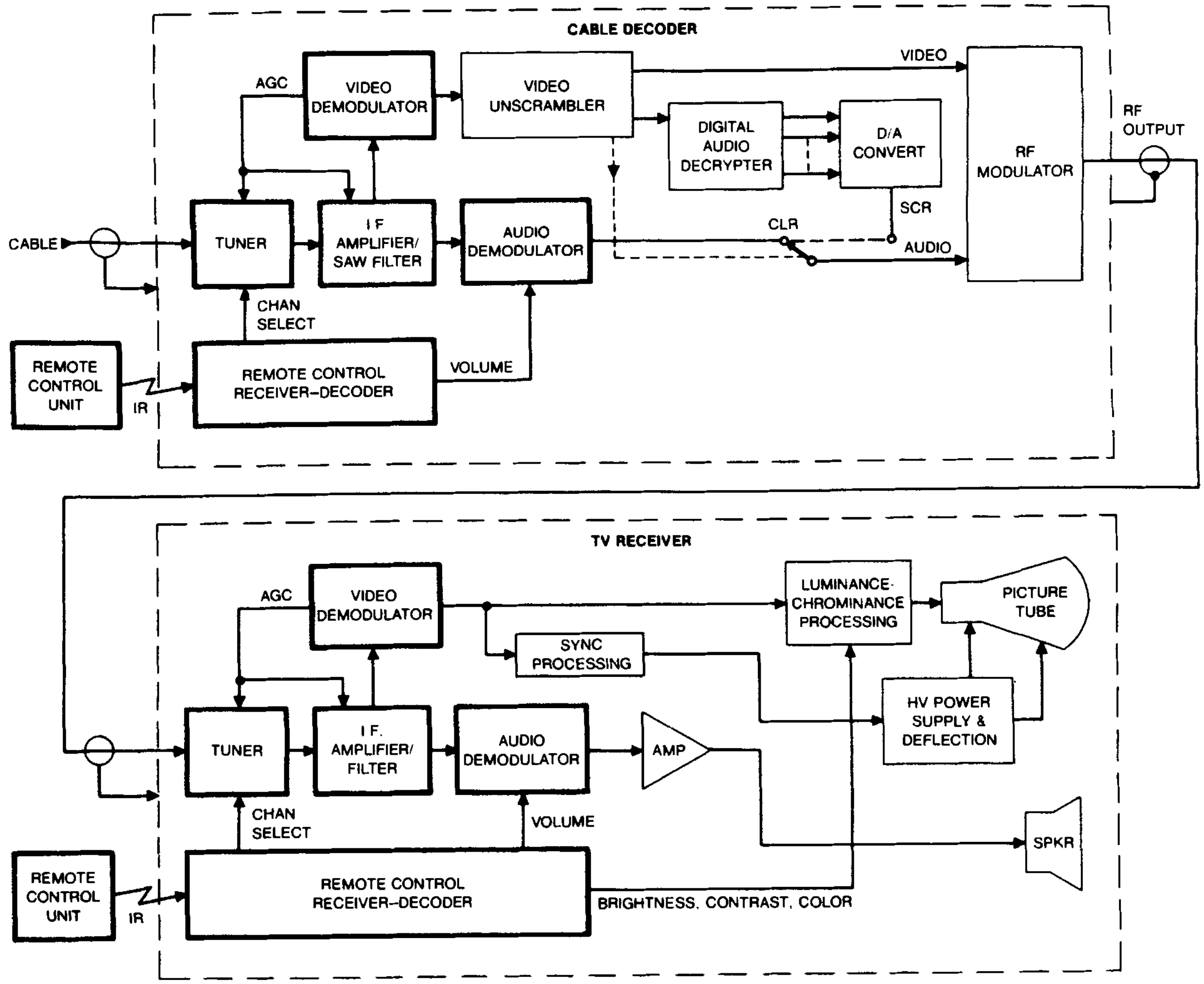


FIGURE I
CABLE DECODER
AND TV RECEIVER FUNCTIONS
(REDUNDANT FUNCTIONS SHOWN WITH BOLD OUTLINE)

Baseband Decoder Approach

Figure 3 illustrates the basics of the approach adopted by the EIA committee in order to achieve improved compatibility between the decoder and receiver. As shown, this approach maintains most of the receiver functions while reducing the decoder functions. However, it requires modification of both the decoder and receiver to include internal interface circuits. These circuits normalize the baseband audio and video signals as well as generate control signals which are exchanged between the receiver and decoder.

In operation, channel selection is performed by the tuner in the receiver. Baseband video signals from the video demodulator pass through the receiver interface circuits and are sent to the decoder. These signals may be scrambled or unscrambled.

The decoder receives the video signals through its interface circuits and sends them to the video unscrambler. The video output from the video unscrambler is then sent back to the receiver through a similar path. Nonscrambled video signals pass through the decoder without modification (transparently). Thus video signals transmitted to the receiver are in standard NTSC format for both clear or scrambled signals (from authorized channels).

The decoder generates control signals which the receiver uses for determining selections to be made for scrambled or unscrambled modes of operation. In the nonscrambled mode, internal receiver AGC control is selected along with audio from the receiver's internal demodulator. In the scrambled mode, receiver gain is controlled by the output of a video level measuring circuit in the decoder and, for OAK Sigma descrambling, audio is selected from the D/A converter in the decoder.

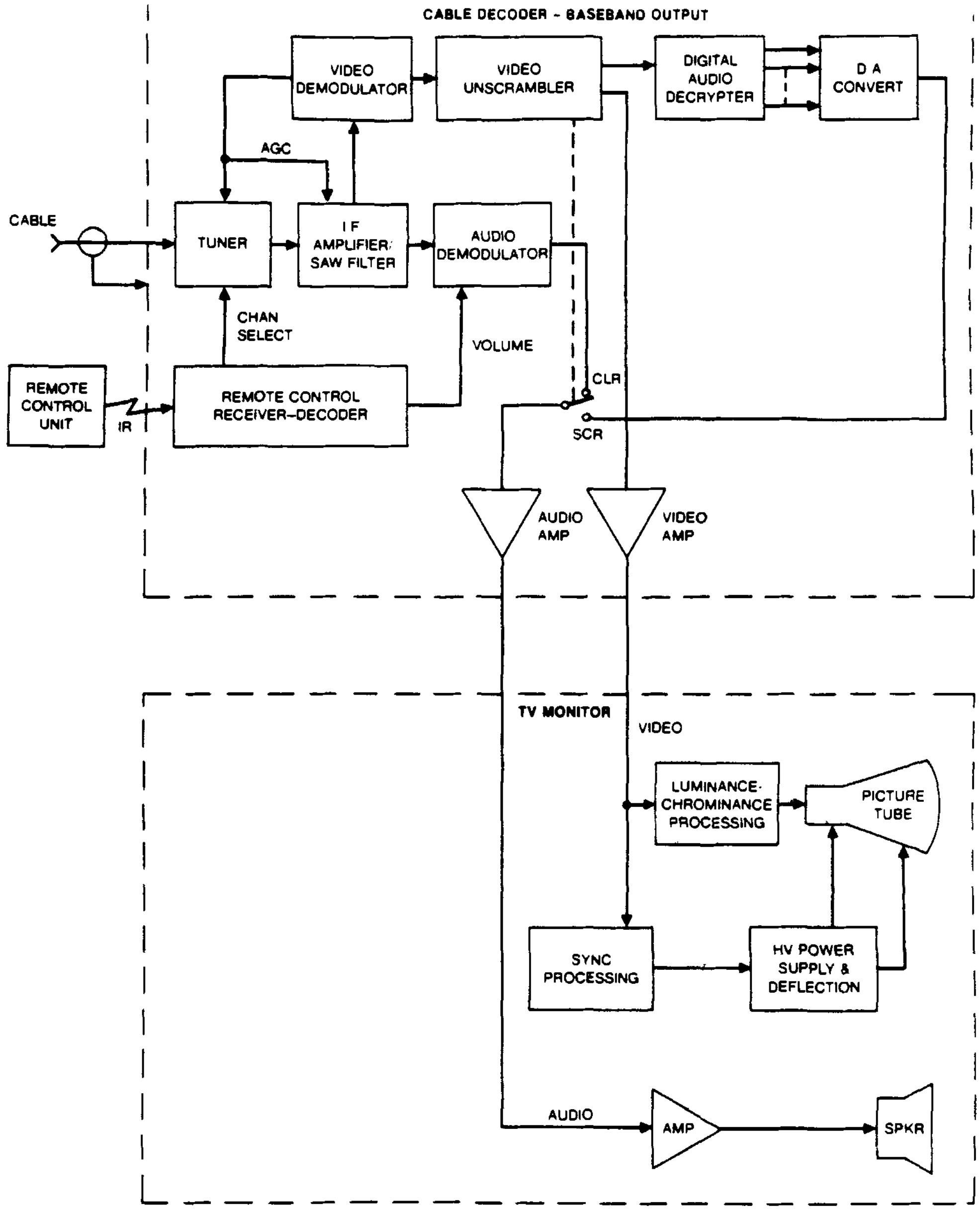


FIGURE 2

CABLE DECODER
AND TV MONITOR FUNCTIONS

Summary of EIA Standard

The following list summarizes some of the items which have been specified by the NTSC Television Receiver Baseband (Audio/Video) Interface Standard (IS-15) developed by the EIA Television Receiver Committee (R-4).

a) Specifies a 20 pin (plus shield) connector of a type used widely in Europe for interconnections with RGB operation, called a Cenelec connector. The connector is to be installed on the rear of receivers and decoders (optional) designed for this standard.

b) Defines the functions of 18 of the pins and associated conductors of an interconnecting cable expected to be less than 2 meters in length.

c) Standard allows for 4 possible interfaces to the receiver from a decoder or other audio/video device. Four interfaces are: monaural, stereo, monaural + RGB, and stereo + RGB.

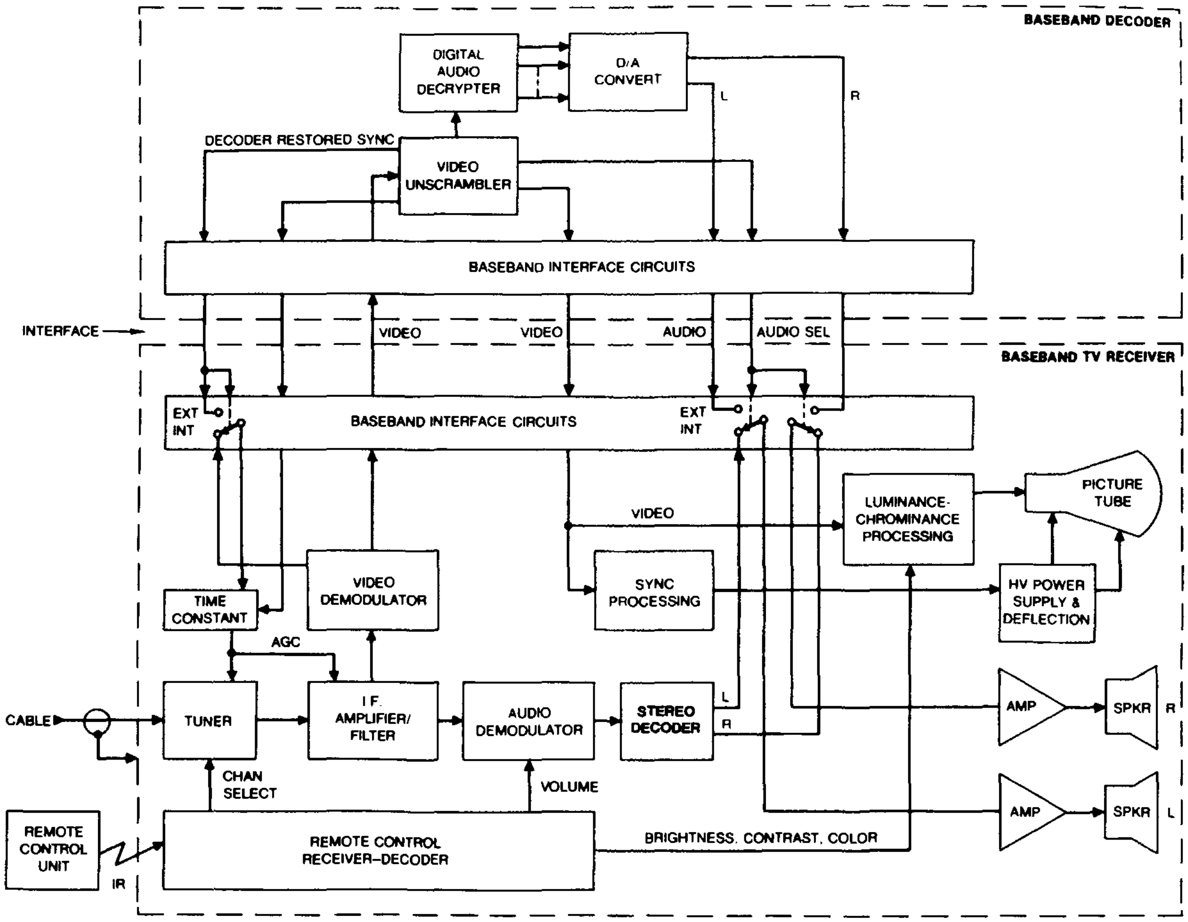


FIGURE 2
BASIC BASEBAND CABLE DECODER AND
TV RECEIVER FUNCTIONS

d) The main baseband video connections between a decoder and receiver are:

Pin 19, video signals from receiver to decoder.
Pin 20, video signals from decoder to receiver. These signals are nonscrambled when pin 19 receives scrambled signals from selected (authorized) channels.
Pin 18, video or control signals from decoder to receiver; same signal as pin 19 during acquisition mode, a DRS (Decoder Restored Sync) for AGC control when operating with a scrambled channel and a high level when receiving a clear signal on pin 19.

e) Audio connections between a decoder and receiver include:

Pin 2, left channel audio signals from decoder to receiver.
Pin 6, right channel audio signals from decoder to receiver.
Note: In monaural reception both pins carry same signal.

f) Control signals between a decoder and receiver (other than pin 18) include:

Pin 1, signal from decoder to receiver to select receiver internal (receiver) or external (decoder) audio source.
Pin 3, signal from decoder to receiver used with signal on pin 18 for selecting slow, fast or normal receiver time constant.
Pin 14, signal from receiver to decoder indicating a channel change or power interruption.

Variations in AGC Control

Television receiver manufacturers vary in their philosophy and methods of achieving AGC. Some use very short time constants in attempting to overcome effects of rapid carrier level changes such as airplane flutter. Others use various longer time constants. For level detectors, peak, gated and other types are employed. Expertise in the design of AGC circuits is apparently scarce;

it has been stated (reference 3) that it is limited to "probably less than twenty experts in the entire world."

AGC Problems Anticipated and Realized

Knowing some of the above variations, the EIA committee anticipated that one of the most severe problems faced in developing the interface standard would be defining the AGC functions with the receiver interconnected to a decoder, especially in the scrambled mode. The overall AGC functions must be shared between the decoder and receiver. Furthermore, the receiver has to provide some degree of AGC control during the acquisition phase in order to deliver usable video signals to the decoder. Achieving this degree of AGC control when dealing with scrambled signals with suppressed or non-existent sync was a major concern of receiver manufacturers.

The committee's apprehension over AGC performance was justified during the first field tests, conducted in January of 1985. At those field tests almost every decoder and receiver interconnected for the first time, exhibited various types of AGC instability. A common symptom was a mode where acquisition by the decoder was followed by a change in receiver gain, which in turn affected the video to the decoder sufficiently to cause loss of acquisition, followed by re-acquistion, etc. The visual result was a televised display flashing wildly between a blank screen and a picture.

Basic AGC Control Functions

Figure 4 illustrates the main functional elements of a typical television receiver AGC control loop. The main function of the overall circuit is the maintenance of a constant video output level while receiving RF carrier levels varying from one channel to the next and possibly varying with respect to time, especially during over-the-air reception.

Video processing involves obtaining a measure of a fixed, repetitive portion of the video level, often the sync pulse, through peak detection, gated sampling or other technique. The processor output is filtered by passage through a low-pass filter, then compared with some fixed reference in order to generate an error control signal. This error signal is then used to control the gain of the IF amplifier and sometimes the tuner of the receiver.

Combined Receiver-Decoder AGC Control Functions

Figure 5 is a simplified block diagram showing the combined receiver and decoder functions involved in control of AGC, with equipment modified for the baseband interface standard.

As shown on the diagram, baseband video signals from the receiver's detector are sent to the decoder through buffer stages in the respective interface circuits. The unscrambler circuits in the decoder provide an unscrambled video output which is then sent back to the receiver.

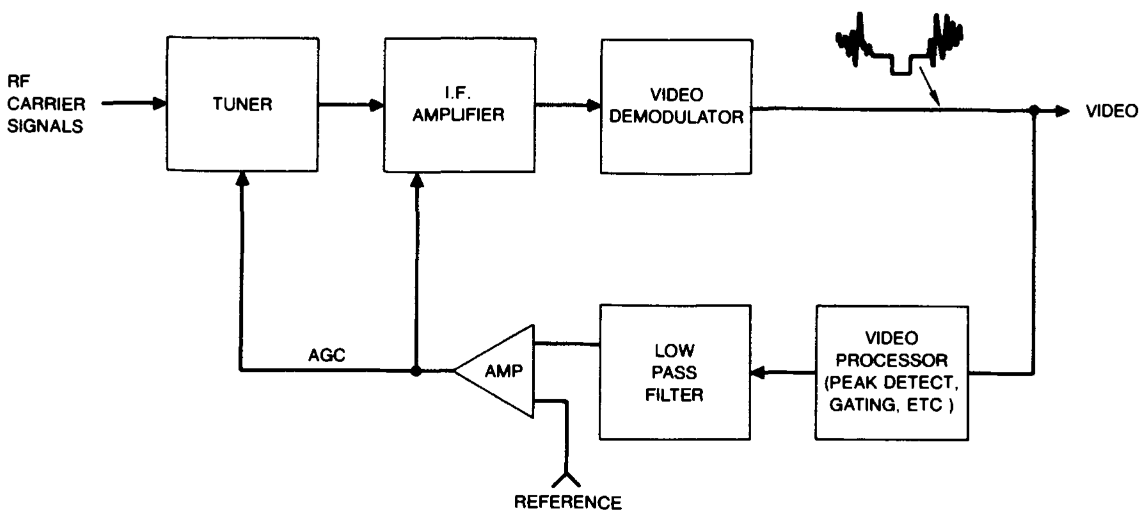


FIGURE 4

TYPICAL AGC CONTROL LOOP

The unscrambling circuits also generate a gating pulse which drives a sample and hold stage. Sampling takes place at the time a recurring reference is received with the scrambled video signals, so that the voltage generated is representative of the video amplitude. This voltage is scaled, compared with an internal reference and the resulting output is gated on and out to the receiver as a DRS (decoder restored sync) signal.

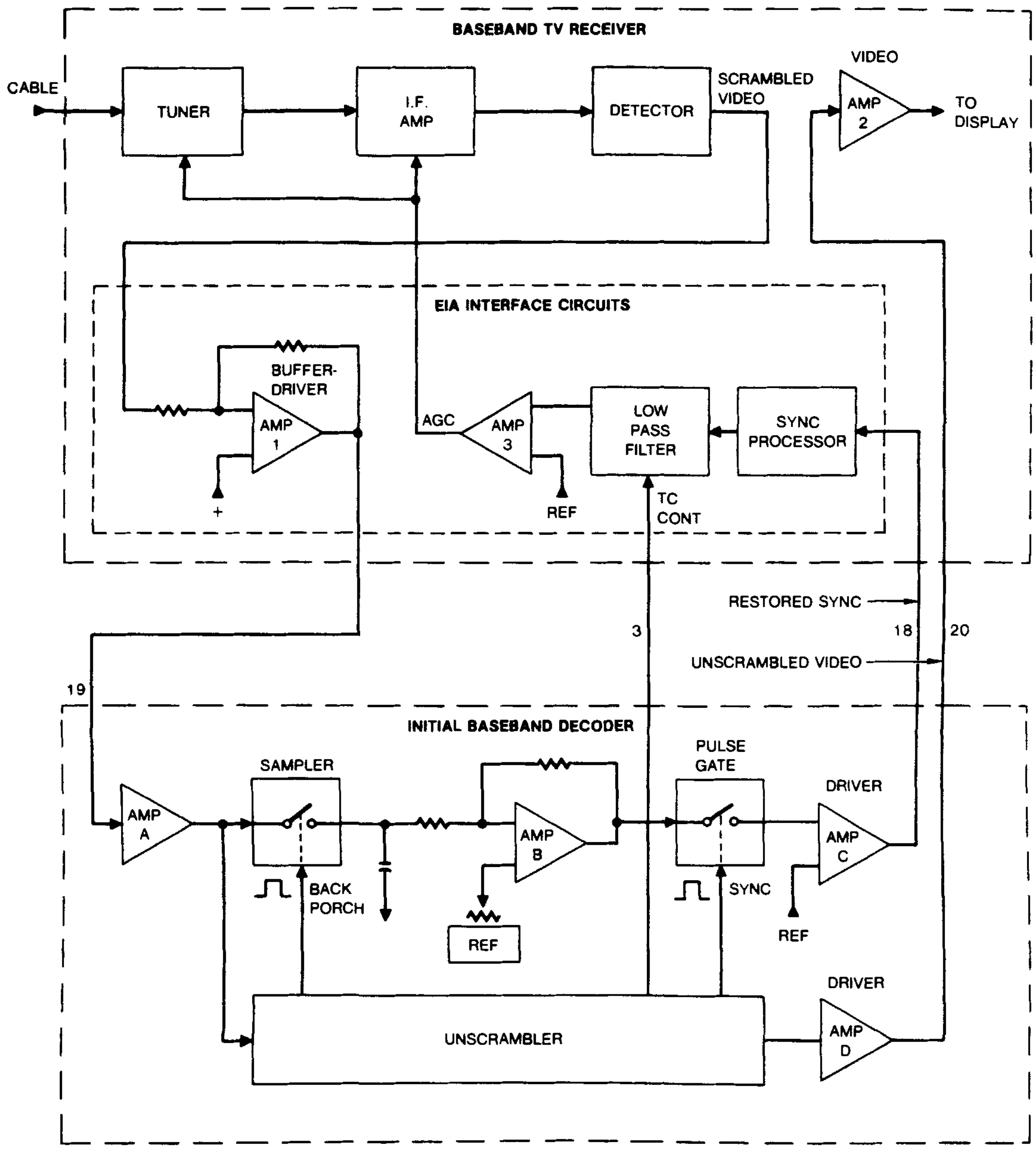


FIGURE 5

TYPICAL AGC FUNCTIONS
INITIAL BASEBAND DECODER AND RECEIVER

At the receiver the DRS signal is typically processed by the interface circuits, passed through a low-pass filter and the result, a slow varying dc voltage, is then used to control the gain of the receiver.

After acquisition the loop settles at a level where the output of the decoder's sample and hold circuit equals the reference on the following comparison stage. With everything operating correctly, this should correspond to an optimum video level to the encoder and DRS level to the receiver.

Achieving AGC Stability for Interfaced Receiver & Decoder

To achieve stability for the combined receiver and decoder the cumulative effects on the phase margin of the AGC system from the combined transfer functions of both must be carefully controlled. The specification provides for selectable receiver time constants. Through judicious selection, minimum interaction can thus be obtained between the time constants of the receiver and decoder. For scrambled signals this selection of time constants is determined by decoder generated control signals.

Note: Time constants were defined in part as the time required to reach 90% of steady state following a step change in the input signal level.

Before the field tests described above, the specifications provided selection between a slow time constant of 20 milliseconds or greater and a "normal" time constant for the receiver. The slow mode was to be selected by the decoder only while decoding (during the acquisition mode).

For the decoder a time constant of 5 milliseconds maximum, was specified initially. With a sampling circuit of the type shown on figure 5, a time constant of about 0.2 milliseconds was obtained.

A problem encountered which contributed to some of the instabilities during the January field tests was that the "normal" time constant differed for each receiver and was in some instants interactive with the time constant of the decoders.

To overcome this problem the committee later agreed to specify both a SLOW and FAST time constants for the receiver, still selectable by a control line from the decoder. These were:

SLOW: 20 milliseconds or greater

FAST: 1 millisecond or less for an carrier increase of 6 dB
2 milliseconds or less for a carrier decrease of 6 dB

Field tests conducted in June demonstrated a marked improvement in the AGC operation for interfaced receivers and decoders indicating a benefit from specifying the time constants as shown.

The latest specifications have incorporated the above SLOW and FAST time constants. In addition a "normal" time constant has been made available for selection at the receiver if the decoder indicates (through signal lines) that a nonscrambled channel has been selected at the receiver.

For the decoder, the time constant specification now calls for a response time of 1.0 millisecond or less, which the decoder can readily achieve.

Video Level Variations

Variations encountered in the absolute level of the video signals delivered to the decoder by different receivers was a severe problem for the original OAK decoders. These variations were verified during the June tests. Using 5 step linearity test video signals, the dc level delivered for each step was different from each receiver. However, the receivers were well within the specifications as written at that time.

In the committee meetings during the development of the specifications, reference was often made to an ideal receiver with a video output as shown in figure 6 (a). Specifically, the ideal voltage output for 0 carrier level was 2.143 volts, for 100 IRE (corresponding to 12.5% modulation) it was 2.000 volts and for sync tip (100% modulation) the output was 1.000 volt. However, the specifications as published in May 1985, allowed video amplitude of 1.0 +/- 0.25 peak to peak and the dc level for sync tip of 1.0 +/- 0.25 volts.

A brief analysis of the operation of the original decoder as illustrated in figure 5 identifies the reason for its sensitivity to absolute levels. The sampler circuit was designed with the expectation of a specific dc level during the arrival of the recurring reference signal present in the scrambled mode. In standard Sigma decoders, this is assured by a factory adjustment in a circuit following the video demodulator, which normalizes the output of the internal receiver in every decoder.

With the receivers used at the field tests any variation in the received reference level was translated into an error in the DRS signal. This in turn caused an incorrect receiver gain setting. The net effect was obervable as a variation in the contrast of the receiver displays, especially when changing between clear and scrambled channels.

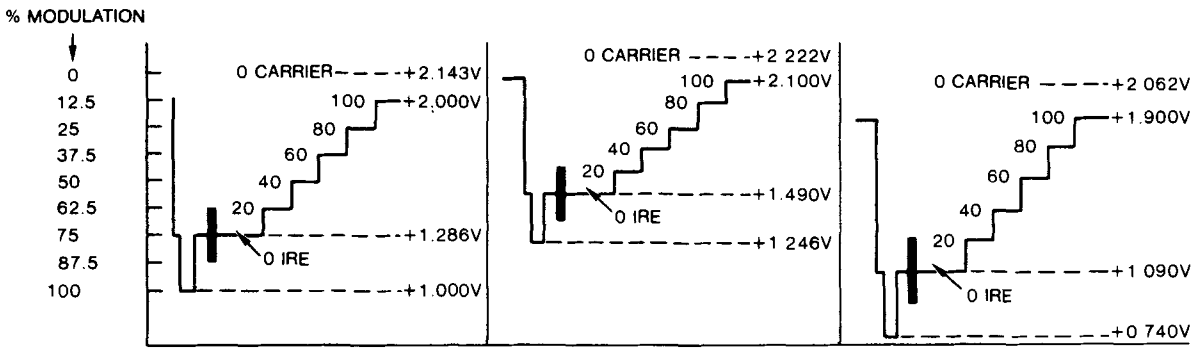
In discussions of recommendations, after the field tests of June 1985, the receiver manufacturers generally agreed that the installation and setting of a video normalizing adjustment (as used in Sigma decoders) was too severe a requirement for mass produced receivers. However, the committee agreed to improve the specifications on receiver video output. As published in the latest specifications they are as follows:

Blanking to Peak White	0.71 +/- 0.1 Volt P-P
Sync to Blanking	0.29 +/-0.06 Volt P-P
DC Level at 100 IRE	2.00 +/- 0.1 Volts

These changes now limit the variations to those shown on figures 6 (b) and (c). But, noting the variations of dc levels which are possible for the 80 IRE steps (near the reference level used in a Sigma scrambled signal) a variation of +/- 15 IRE units relative to the optimum level can still occur.

Modification for Two Reference Levels

On the basis of the above specifications, previous experience with the OAK Orion satellite scrambling system and also recommendations made by committee members, a decision was made to incorporate two reference levels into the overall scrambling system, for the EIA baseband equipment.



(A)
OPTIMUM SIGNAL
VIDEO = 0.71V P-P
SYNC = 0.23V P-P
100 IRE = 2.00V

(B)
LOW LIMIT SIGNAL
VIDEO = 0.61V P-P
SYNC = 0.23V P-P
100 IRE = +2.10V

(C)
HIGH LIMIT SIGNAL
VIDEO = 0 81V P-P
SYNC = 0 35V P-P
100 IRE = +1 90V

FIGURE 6

VIDEO TOLERANCE RANGE
LATEST SPECIFICATIONS

With two reference levels a measurement of the difference between the two levels provides a good measure of the amplitude of received video signals. And more importantly, with a properly designed differential circuit, the measurement can be obtained while largely ignoring the absolute dc levels common to both of the received references.

The encoders used with the system were modified to provide a second reference level (0 IRE) for a few lines during each vertical blanking interval of the scrambled video signal. The normal reference level, presently 75 IRE, which is transmitted once every line, was left unchanged.

Decoder Modification for Two Levels

Initial laboratory tests with a decoder modified to receive and process two reference levels demonstrated very good performance, with one exception. The response to step changes in the video input was slowed down due to the fact that sampling of the video signal for the new reference was restricted to only one sample per field (i.e. 16.6 milliseconds). Initial considerations towards sending both references once per line had to be rejected since this would have required a major system re-design.

Consultation with one of our colleagues (reference acknowledgement) resulted in the design of a unique circuit capable of achieving the fast decoder response required in spite of the slow sampling of one of the references. The basic circuit configuration is shown on figure 7 along with a diagram of a portion of the scrambled signal applied to its input. A summary of its operation is as follows:

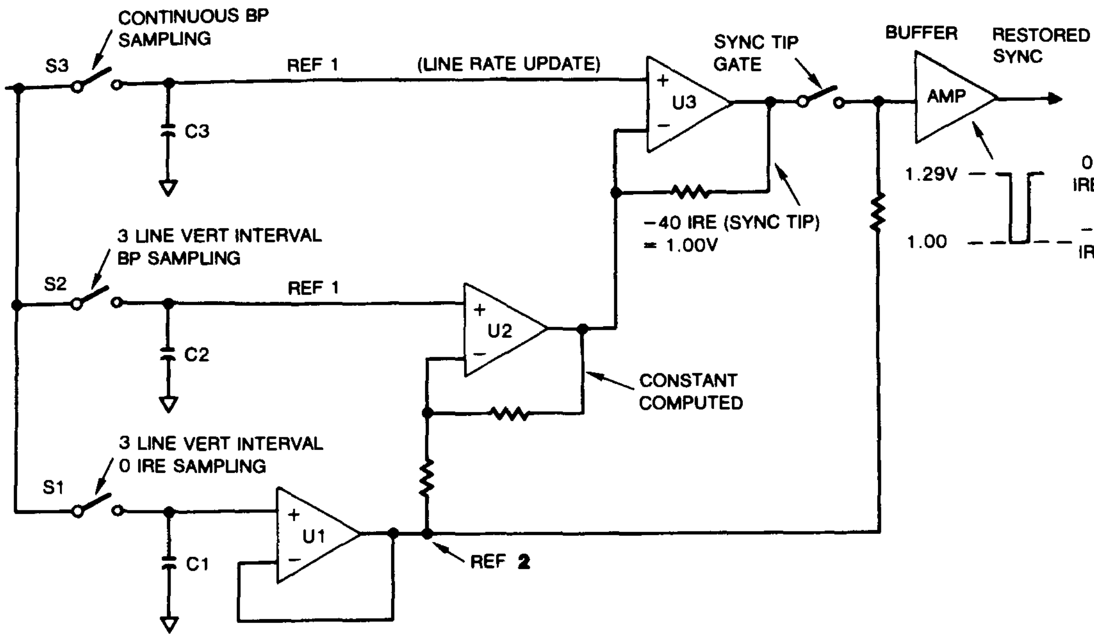
One reference signal is transmitted during the back porch interval also used for sending the color burst. This occurs on every line thus allowing a fast response time. The second reference is only transmitted as a video signal for a few lines during the vertical blanking interval.

Switch S1 closes during the arrival of the second reference signal and this level is stored in C1. Switch S2 closes for the same lines but during the arrival of the first reference signal, which occurs on the back porch of every line and this level is stored in C2. Switch S3 also closes during the arrival of the first reference but on every line and this level is stored in C3.

Operational amplifiers U1 and U2 are used to compute a constant based on the difference between the levels stored in C1 and C2. The output of U2 is thus a constant which may change from one receiver to the next but will not change even with video level changes or after selection of different channels.

Amplifier U3 is used to compute the sync tip level, based on the nearly static input level from U2 and the fast changing input from C3. The result is a sync tip level signal which also responds rapidly, well within the 1.0 millisecond maximum specified for the decoder.

As shown in figure 7, the actual restored sync output is generated by sending out the sync tip level through a switch (actuated during sync time) and an output buffer stage. The rest of the time when the switch is open, 0 IRE level is sent out. This composite output



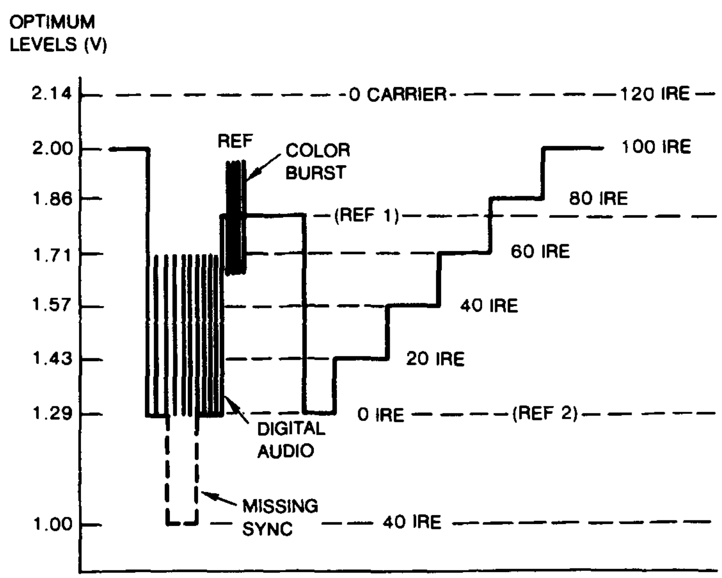


FIGURE 7

SCRAMBLED SIGNAL - TWO LEVEL PROCESSING

is the DRS (decoder restored sync) used by the receiver for AGC control, as described earlier.

Final Baseband Decoder Interface

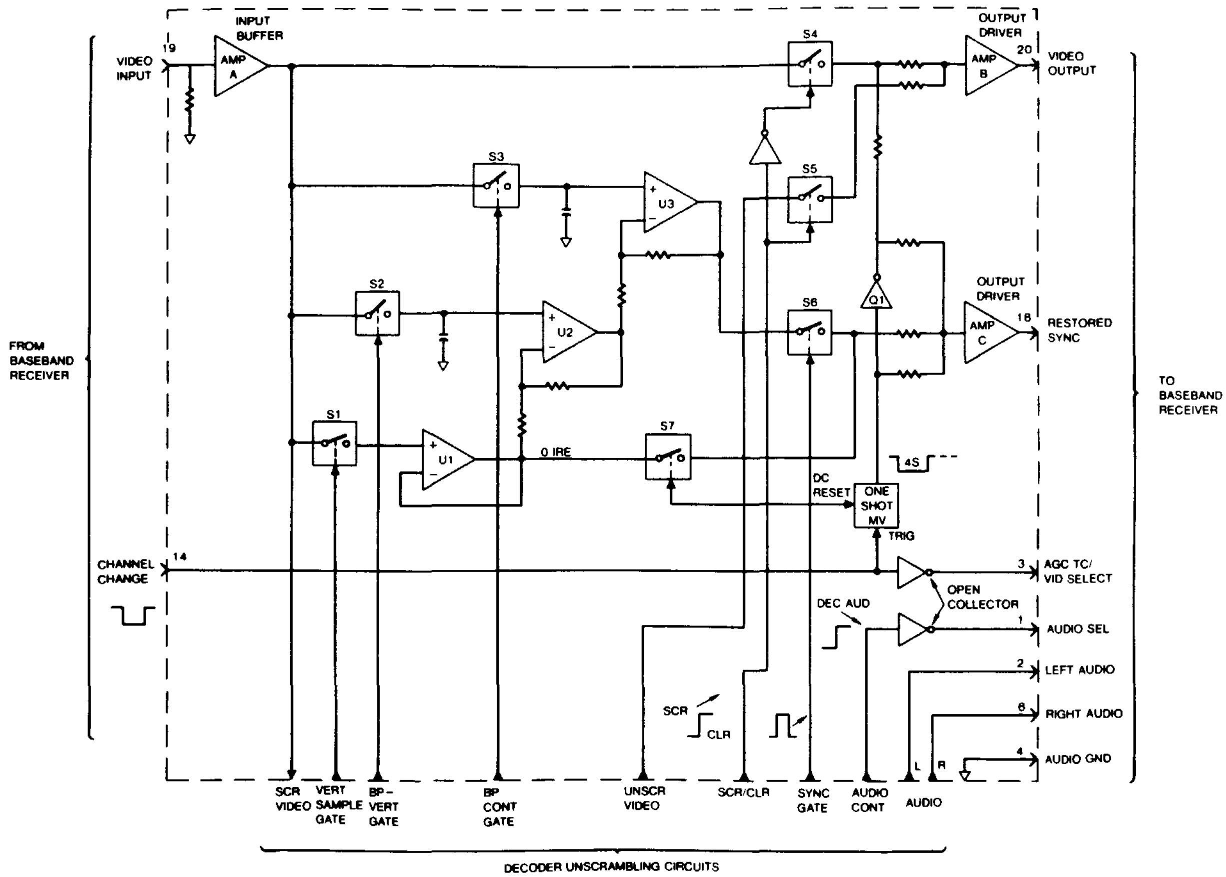
Figure 8 is a block diagram illustrating the overall functions provided within the decoder in order to achieve the baseband interface requirements. A brief description of these functions is as follows:

Video input signals from the receiver are received through input buffer amplifier A. For unscrambled signals these pass through switch S4 and the output driver B and back to the receiver in a transparent mode.

After receiving a channel change signal from the receiver a one-shot multivibrator is actuated for a few seconds. During this time transistor Q1

FIGURE 8

BLOCK DIAGRAM
FINAL BASEBAND DECODER INTERFACE



is turned off which allows the sending of video signals from S4 through output driver C, providing transparency for the input video out of the restored sync port (18). If the received video is unscrambled the one-shot will time out, driving Q1 to interrupt the video, while sending a high level out through output driver C indicating a clear channel to the receiver.

When a scrambled channel is received and acquired, the unscrambling circuits will:

a) Open switch S4 interrupting the incoming video signals path to the output.

b) Close switch S5 allowing the unscrambled video signals to pass through output driver B and on out to the receiver.

c) Reset the one-shot multivibrator.

d) Close switches S6 and S7 to send the restored sync signal to output driver C and on out to the receiver.

The operation of S1-S3 and U1-U3 has been described in the previous section. The rest of the functions are self evident.

Final Performance

The decoder, upgraded to the configuration described in the last two sections was used during the field tests conducted in November 1985.

Overall the performance was quite satisfactory. The previously experienced sensitivity to variations in different receiver's outputs was no longer a problem. The worst thing observed, with some receivers, was a barely perceptible flicker in the picture displayed. This was considered a prototype phenomena to be resolved in producing equipment for operating with this interface.

The first public demonstration was the operation with a modified Sony receiver, during the Western Cable Show, in Anaheim CA., during December 4-6, 1985.

SUMMARY AND CONCLUSIONS

The specifications of the EIA developed interface standard relative to decoder design and a review of the development of a compatible decoder have been presented.

The specification has other applications not covered by this paper.

The process of developing a standard of this type through a committee effort is sometimes a tedious experience. There were the expected conflicting interests among the participants. But necessities often imposed by the marketplace do provide a positive drive towards achieving the benefits of standardization.

The final standard developed has many good attributes and with further communication among future users, it should be effective and acceptable. Actions and conditions necessary for successful adoption of the interim standard have been discussed elsewhere (reference 4). Because of this and the pleasant relationships established with other participants, the overall participation was a rewarding experience.

Note: Any opinions stated in this paper are those of the author and are not intended to represent those of other participants or of the EIA.

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ACKNOWLEDGEMENT

Thanks are extended to Jim Holzgrafe whose assistance in this project, especially in the unique circuit solution described herein, was extremely helpful.

DIGITAL AUDIO FOR CABLE TELEVISION

by

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GENERAL INSTRUMENT CORPORATION

ABSTRACT

Digtal Audio provides unmatched signal security. Sixteen Bit Linear Pulse Code Modulation offers the highest level of audio performance, but uses the most bandwidth and is the most expensive digital audio system. For a premium audio service, it is still the best choice. Digital audio for video programs is best served by an inband system. Dolby Deltalink Adaptive Delta Modulation offers the best bandwidth efficiency of the companded digital systems and provides very high audio quality as well as low cost. Using Deltalink ADM, BTSC can be replaced with a secure digital transmission. QPSK modulation of the sound carrier is preferrable to in video ASK on a cost basis.

INTRODUCTION

There are two primary applications for digital audio on cable. The audio portion of a video program may be digitized. Premium audio programming independent of video is another ideal application for digital transmission.

Digital audio has two primary advantages over competing analog systems. The signal security provided by numerical encoding techniques is unmatched in analog systems. Digital transmission allows the identical audio quality to be received as is transmitted, independent of cable plant variation. Digital audio services can be much more forgiving of thermal noise and distortion than analog modulated video and audio signals. In other words, service calls will be generated from poor pictures before a digital audio service is affected.

DIGITAL SAMPLING SYSTEMS

Digital sampling systems are numerous. These systems are different methods of converting from a continuous analog audio signal to a digital data bit stream. The basic trade-off in these systems is audio quality vs. data bit rate.

Linear Pulse Code Modulation (LPCM)

LPCM is the sampling technique used for Compact Disks (CDs). The CD sampling rate is 44 KHz with 16 bit binary resolution. There are 65,536 evenly spaced points where each audio sample can occur. The Signal to Noise ratio (S/N) of LCPM is equal to the dynamic range and is 6 dB/bit. For 16 bit LCPM, the CD case, the S/N is 96 dB. The resultant bit rate is 2 channels x 16 bits x 44 KHz sampling rate = 1408 KB/S.

Assuming a 25% data overhead factor is required for control, data framing, and error correction purposes at the PCM receiver, the final transmission bit rate for CD quality LPCM becomes 1408 KB/S x 1.25 = 1760 KB/S. A T1 telephone modem, which carries 24 voice channels, can handle only 1544 KB/S.

Because of the incredibly high bit rate for CD quality LPCM some type of compromise is often considered. Two audio properties should be considered here. Low frequency audio needs greater signal amplitude handling capability than high frequency audio does.

Noise 96 dB below a signal level is inaudible. 30 dB higher noise is also inaudible. CD quality LPCM allows for greater S/N than is required, as well as greater high frequency amplitude handling capability than is necessary.

In an effort to reduce bit rate a usually accepted practice for transmission is to limit the audio bandwidth to 15 KHz, alowing a 32 KHz sampling rate. For 16 bit LPCM the new transmission bit rate becomes 2 x 16 x 32 x 1.25 - 1280 KB/S. This is still a very high bit rate. As a result further techniques are often used to reduce bit rate.

Instantaneous Digital Companded PCM (IDC PCM

IDC PCM or non-linear PCM uses progressively increasing step sizes. The distance between steps for high amplitude signal is much larger than the distance for low amplitude signals. Commonly used curves are μlaw and Alaw. The result of this type of sampling is an increased dynamic range for a given number of bits compared with linear PCM, at the expense of reduced instantaneous S/N. The noise level tracks the signal amplitude, increasing as the signal increases. If this compression technique is extended too far, the noise will become audible. IDC PCM does provide the possibility of reduced cost by allowing lower precision Digital to Analog (D/A) converters. If 10 bits are retained, the transmission bit rate will be 2 x 10 x 32 x 1.25 = 800 KB/S.

Block Companded PCM (BC PCM)

BC PCM uses storage of LPCM for a fixed time interval to determine the maximum bit level that occurs within that time interval or block. Only the desired number of bits downward from the maximum in the block are retained for transmission. Data is carried to the receiver indicating what bit range is to be used for each block. This range data must be extremely well protected against errors, as the errors will have a long lasting effect. If too few bits are retained, the noise will become audible. 10 bits is considered an acceptable limit so the bit rate is 800 KB/S.

Analog Companded PCM (AC PCM)

AC PCM uses an analog compander in front of a PCM Analog to Digital (A to D) converter. Bit rate and cost are saved by using a lower precision A to D converter. Both variable gain and variable pre-emphasis may be used to minimize the apparent noise level. A disadvantage of this system is the transient response errors which analog companders exhibit from changing gain after the signal changes, rather than looking ahead as BC PCM systems do. Some systems (such as the digital audio used on 8MM video tape) combine analog companding and instantaneous digital companding to reduce the bit rate to 8 bits per sample. For 15 KHz audio bandwidth with 8 bits/sample, the transmission data bit rate is 2 x 8 x 32 x 1.25 = 640 KB/S.

Dolby Deltalink Adaptive Delta Modulation (ADM)

Deltalink ADM differs from PCM in that sampling occurs at a rate much greater than twice the maximum signal frequency. Each sample can take on only two levels. The sample or step is really a correction signal which indicates whether the real time average of the preceeding steps is larger or smaller than the present audio level. The audio is recovered by integrating the series of steps which make the data stream. Companding is used to vary the size of the steps. In the Deltalink ADM system the comanding is similar to that of block companded PCM. Storage is used to look ahead so that transients are not distorted. The step size control signal is converted to a delta-sigma data stream and inserted with the audio data stream. This data is evenly weighted and has a very low bandwidth so that it does not require elaborate error protection like block companded PCM.

In addition to step size companding variable pre-emphasis is used to maximize the instantaneous S/N. The variable pre-emphasis control is handled in the same manner as the step size with look ahead storage and data inserted in the main delta mod data stream.

Deltalink ADM has two distinct advantages over PCM systems. The first is lower cost audio reconstruction. Because of the high sampling rate no brick wall filter is required. No precision D to A converter is required. Less logic is required to reconstruct the audio signal. At the receiver no block memory is required. Because all bits are of equal significance in delta modulation, much higher error rates can be tolerated than in PCM systems. With the relatively high C/N available in cable systems by data transmission standards, delta modulation requires no error correction or its associated logic and framing memory.

The most significant advantage of Deltalink ADM over PCM systems is the lower bit rate required. Because error correction is not required, the data overhead factor can be 10% rather than 25%. The data bit rate for a stereo audio channel with 15 KHz bandwidth, 85 dB dynamic range and 60 dB S/N is 2 x 208 KHz x 1.1 = 458 KB/S.

TRANSMISSION TECHNIQUES

There are numerous data transmission systems which could be used for digital audio over cable. Three systems will be considered here which use bandwidth efficiently and are implemented at reasonable cost.

1. QPSK Out of Band

Quadrature Phase Shift Keyed (QPSK) modulation of a carrier which is not part of a video program channel is suitable for premium audio services. QPSK with non-return to zero (NRZ) coding gives two bits per hertz bandwidth efficiency (bit and frame sync are already accounted for in the overhead included in the final bit rate calculations). A 1.5 bandwidth factor for interference to analog signals is practical.

In addition to bandwidth efficiency, QPSK has excellent noise performance. If a QPSK signal is carried 20 dB below video carriers and a noise bandwidth of 1 MHz is assumed, then a worst case situation of 36 dB video C/N would result in a QPSK carrier to noise of 22 dB. The probability is extremely low that a bit error will occur under these conditions due to thermal noise in a life time. Outages are more likely to interrupt a QPSK digital audio service than poor C/N.

NRZ QPSK out of band can handle all the types of digital audio sampling because the bandwidth used need not be backward compatible with analog channel spacings. The most preferrable sampling method in this case is 20 KHz bandwidth 16 bit linear PCM. A channel spacing of 1.5 time Nyquist bandwidth is assumed, giving (1760KB/S ÷ 2) x 1.5 = 1.32 MHz for NRZ QPSK. This would allow only four audio channels inside a video channel, but it would provide CD quality directly into a subscriber's home. Cable is presently the only medium where CD transmission to the home is possible.

Out of band QPSK used for video program audio presents both financial and operational difficulties. A separate addressable digital audio converter cannot compete with a single converter for video, analog and digital audio. The combined converter shares tuning, addressing and display functions, etc. In the future, if all video channels require multi-channel sound and there are numerous channels of premium audio service, the available bandwidth for out of band QPSK will disappear rapidly.

2. Time Division Multiplex (TDM) Vestigal Sideband (VSB) Amplitude Shift Keying (ASK)

TDM VSB ASK may be used in the video Horizontal Blanking Interval (HBI). Assuming 8.25us out of 63.5us would be usable for data and a 7.16 MB/S bit rate (2 tims the color subcarrier frequency) were used with NRZ coding the available effective bit rate would be 930 KB/S. Block companded PCM or Deltalink ADM would be usable with the available bit rate.

A disadvantage of high speed TDM VSB ASK is the stringent frequency and group delay response requirement over the whole transmission path, including the modulator, cable plant and converter demodulator. Another disadvantage is the cost of reconstructing proper video horizontal, vertical and color sync for output to the TV.

3. QPSK Sound Carrier

A QPSK Sound Carrier is possible with an interference bandwidth of 500 KHz so that 4.2 MHz video and -1.25 MHz VSB from the upper adjacent channel are not disturbed. The available bit rate for QPSK NRZ is (500 KHz ÷ 1.5) x 2 = 667 KB/S. According to the previous calculations there are two types of sampling systems which have low enough bit rates. The systems are PCM companded to 8 bits and Deltalink ADM. Deltalink ADM is preferrable to PCM on a cost and error immunity basis.

A desirable feature would be to have an inband digital audio system capable of a stereo channel and a monaural channel simultaneously so that the digital audio could be used as a replacement for BTSC. Further investigation will show that this is only possible for the available bit rate with Deltalink ADM.

CONCLUSION

The two markets for digital audio can best be served by two different digital techniques. A premium audio service should be truly premium, with unsurpassed performance even if it is an overkill. CD compatible PCM should be used for premium audio.

Video program audio should be inband for convenience and cost purposes. Deltalink ADM is the only system which can fully replace BTSC with security and high fidelity.

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DIGITAL DATA IN CABLE SYSTEMS: THE BASICS OF ERROR CONTROL

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ABSTRACT

Analog video and audio have long been the mainstream signals in cable systems. With the appearance of scrambled programming and addressable subscriber decoders, cable systems silently entered the digital world.

As in any communications system, the cable networks must contend with and compensate for imperfect or noisy signals. The analog world can tolerate noise much easier than the digital world. Moreover, analog methods for digital noise filtering are ineffective against errors in digital data channels. This paper examines digital error control, its effects on customers and equipment, and presents an overview of a few techniques used by equipment designers to improve data reliability and system performance.

1.0 INTRODUCTION

The cable system of yesterday was a distributor of simple analog video and audio programs to domestic subscribers unable to receive direct television broadcasts. The cable system of today is a sophisticated multi-channel network whose operators offer a number of programming packages and services to a larger and much more diverse subscriber population.

Although communication satellites have been with us since the 1960s, it has taken nearly twenty years to design and build affordable technology that could link local cable system networks with nationwide broadcast satellites. Cable television now reaches not only into the rural market, but into the urban and fast growing suburban markets as well.

The marketplace today offers a wide variety of television programming that includes entertainment, news and information. To provide the subscriber with a variety of program packages and billing rates, as well as to contain and secure the product, programmers and cable operators installed scrambling equipment that, to varying degrees, made the video and audio unrecognizable.

Recently, scrambling equipment came between the programmer and the cable operator, in addition to scrambling equipment between the operator and subscribers. It was a natural step for the manufacturers of scrambling systems to consider innovative designs that have since changed the industry. Some of these design features are: encrypted digital high-fidelity multi-channel audio, addressable decoder control, and digital data channels.

The art of scrambling became a science. Assigning each decoder a unique address, or name, permitted selective decoder authorization which has lead to pay-per-view and other impulse mode products. Computerized decoder control and individual decoder attention is now the basis for most scrambling systems. All these necessarily depend upon digital remote control.

2.0 BASE-BAND TRANSPARENCY

So, it is not just analog anymore. Your cable systems and satellite receivers relay control information that is often inserted in the Vertical Blanking Interval (VBI) of the video base-band signal. Descrambling decoders and re-encoders are controlled by these digital pulses that are organized into meaningful messages which the decoding equipment understands. Analog audio is digitized and usually inserted in the Horizontal Blanking Interval (HBI) along with other information. These systems are described as being base-band transparent, i.e. all video, audio and related digital information resides within the allocated video bandwidth.

Sub-carriers are also a design option for digital pathways, but these are used at the expense of additional bandwidth and complexity. The same sub-carrier space might just as well be used for additional commercial channels and the capture of otherwise lost revenues. The same may be said of systems that require extended video bandwidths to pass all required control signals. From this point of view, base-band transparency, the ability to send digital information in the allocated video bandwidth, is the economical "best-buy" in terms of price/performance.

3.0 THE NOISE PROBLEM

What makes all this exciting is the one-way control traffic - we can tell a decoder what to do, but it will be the subscribers that call us whenever their decoders are in a most undesirable state. Decoders are "Listeners", i.e. they cannot talk back to their controller. In the presence of noise, however, just what is it the Decoders are listening too? This situation provides a design challenge to which there is no perfect solution, but a lot of thought and clever implementation has made the open-loop control problem a manageable one.

Noise is a corrupting influence. Depending upon its relative intensity, a message may be crystal clear or entirely unrecognizable. In many cases, noise has a subtle effect, not as much noticable as it is potentially irritating.

The analog world perceives noise as a "distortion" while the digital world may perceive noise as a "bit-bomber". Figure 1 illustrates this point. Analog signals

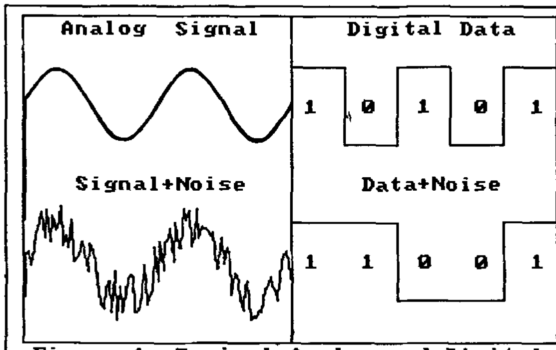

Figure 1. Typical Analog and Digital noise effects.

affected by additive noise exhibit amplitude and frequency component mutation. Most analog signals that we send are naturally smooth and continuous. But noisy analog signals can be treated with a well defined science that: (1) compensates for amplitude losses with increased gain, and (2) uses band-limiting filters that narrow the permissable frequency spectrum within which our signals appear. Other design factors, e.g. modulation, are also an important part in noise elimination, but gain and filtering are basic to analog noise reduction.

In contrast to analog, digital noise has a significantly different and potentially serious effect. First, digital signals are not smooth and continuous. They usually contain elements with discrete levels called bits, i.e. BInary digiTs. Each level is assigned a unique value or interpretation. Second, these bits are grouped together to represent predefined packets of information; the original information could be digitized analog such as voice and music, or computer generated command messages (e.g. "Decoder-#123-Authorized").

In "binary" or two-level digital systems, each bit takes on a value of either a "0" or a "1". Figure 1 shows an example of a transmitted digital signal with a value "10101". Imagine being a subscriber and that somewhere along the way to the decoder, impulse noise (like that from your neighbors' lawnmower) instantaneously alters two bits in this message that now is decoded as "11001". Suddenly, before your very eyes, your favorite movie has turned into a kalidescope of colors, zig-zags and rolling black lines. Your family may well ask, "what happened?" Without digital error control, this decoder may have translated the received command as a "Decoder-#123-Deauthorize" command and so it immediately stopped descrambling your movie (with no thanks to your neighbor, of course). Such a pity. Is this a case where the cable system gets the blame? Who would you call?

In short, analog noise can be tolerated and effectively minimized using classical design techniques. However, digital noise cannot be tolerated so it must, therefore, be error controlled but in a completely different manner.

4.0 ERROR CONTROL FUNDAMENTALS

The science of digital communications is well described mathematically and has been successfully implemented over the past two decades. Rather than dwell on information theory and esoteric concepts such as the Shannon Limit and channel capacity (which are best left to other references [1]), it is usefull instead to discuss some fundamental concepts used in digital error control.

4.1 The Error Control Rule

When casually discussing with friends the merits of any digital error control method, it is wise to remember two rules-of-thumb:

1. "Some is better than none."

2. "More is not necessarily better than less."

Although these rules may apply to many choice decisions, they especially apply to digital error control in cable system networks. The first rule recommends some type of effective error control. Just having "error detection" capability alone would have prevented the inadvertant deauthorization of Decoder-#123 as previously discussed. Advanced methods allow "error correction," i.e. actually recovering the original message even though is was received incorrectly.

Error detection and correction (EDC) methods vary widely; the simple methods are less expensive (of course) but have definite limitations. The more exotic methods prove to be very effective but resort to expensive overhead and processing demand. Levels of improvement are in terms of dB communication efficiency, i.e. a computed difference, in Signal/Noise per bit for a given bit-error rate, between the coded and uncoded messages. Without EDC there is 0 dB gain. Modest coding gains of 1 to 3 dB can be achieved using simple "block-type" codes; moderate coding gains of 4 to 7 dB and maximum coding gains of 8 dB or greater can be achieved using sophisticated "block-type" codes, "convolution-type" codes and "concatenation-type" methods [1].

The designer must match overall system performance criteria such as response time and low C/N survivability, with customer demand, end-product cost targets, development time and the nature of the communication channel itself. The second rule-of-thumb, therefore, applies to this evaluation and selection process.

4.2 The Noise Limitation Rule

C. E. Shannon was the founder of modern information theory. His work in 1948 and throughout the 1950s, together with a rapidly progressing technology, provided the foundation for all modern communication systems. An important idea he introduced stated that [1]:

> Noise does not limit the level of reliability of a communication channel, but it does set a limit on the rate of reliable information transfer.

This implied that the message rate, or rate of information transfer, was directly related to channel noise. The lower the noise, the greater the allowable message rate; inversely, the higher the noise, the slower the message rate to achieve reliable information transfer. If you send a message slow enough or often enough, the message will eventually get through. There are, as discussed previously, practical considerations that restrict these message rates in real systems. But, in general, this rule has lead to a wide variety of error control techniques that attempt to maximize information transfer within noisy communication channels.

5.0 BASIC ERROR CONTROL CONCEPTS

There are three elementary concepts in digital error control. These are:

1. redundancy
2. interleaving
3. parity

Each is briefly discussed below.

5.1 Redundancy

The first of these is redundancy. The first of these is redundancy. Redundant information is information that is repeated in the same or equivalent form, as demonstrated at the beginning of this paragraph. The Noise Limitation Rule suggested that with enough redundancy, any message could be reliably sent in any noisy channel. Indeed, this rule was well applied to space exploration satellites that relied heavily on redundant message transmission. And at the millions and billions of miles that separate the Earth with these far gone travelers, it seems like a miracle that tracking stations can still hear their whisper amongst the galactic noise within which they exist.

The obvious disadvantage of redundancy is the penalty of duplication. Decoding time, storage and effort are required for each message. If there are a lot of messages, then for a simple 2-of-3 redundant majority technique, the entire series of messages would take 3 times as long to send and decode as it would if the series were sent but once. (By the way, always send an odd number of repeats for majority voting decisions. A firm decision cannot be made with only an even number of choices - one says yes and one says no, which way do we go?)

5.2 Interleaving

In the pursuit of reliability, add-on error control codes necessarily increased the length of the original message. In modest- and moderate-gain methods, the amount of benefit was somewhat limited. If a massive noise pulse obscured more than one or two bits in a message, it was impossible to reconstruct the original information from the received noisy message.

Rather than allow a single message to receive the noise burst, why not spread the noise around? This at first might seem ludicrous - why corrupt a perfectly good message? The answer is explained as follows.

Burst noise has localized effects, i.e. bits tend to get corrupted in a short sequence corresponding to the actual noise burst interval. Where there is burst noise there are bit errors. Error detection and correction methods have a limited capability to detect and correct bits; usually one or two bits can be efficiently corrected in real-time systems. If the messages are organized such that each transmitted message is a collection of bits from two or more messages, then bit errors in the received message can be spread across more than one message when the information is reassembled into original form. Thus, bit errors per message are reduced.

This result is desireable since the number of bit errors per message is very small and can be readily detected and corrected with relatively straighforward and fast EDC methods. As an example, say that we must send two messages to a specific Decoder (see Figure 2):

Message #1: ABCDEF
Message #2: 123456

A simple transmitted message stream would look like

ABCDEF,123456

where Message #2 follows Message #1 in sequence. If there was, for example, a noise burst in the first message such that the receiver collected

ABxyzF,123456

where "CDE" were changed to look like "xyz", and the receiver could only correct up to two-bit errors, then Message #1 would have to be discarded altogether and the information would be lost.

On the other hand, if Message #1 were interleaved with Message #2 such as swapping every other bit between messages, i.e. B with 2, D with 4, etc., then the new transmitted message stream would look like

A2C4E6,1B3D5F

and if that same noise burst blasted three bits in Message #1 such that the received messages were

A2xyz6,1B3D5F

then the reassembled or deinterleaved messages would have the patterns

ABxDzF,123y56

Now the receiver error processing can detect and recover the original messages since, in this example, there were no more than two bit errors resident per message.

So, by interleaving and deinterleaving, bit errors can be reduced per message. This allows the implementation of less expensive and faster EDC methods at the cost of additional bit-swapping in the encoding and decoding stations.

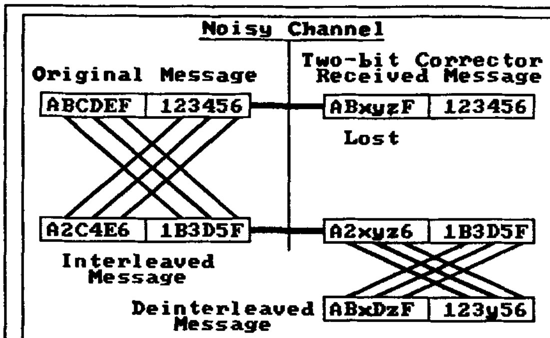

Figure 2. An example of Interleaving to reduce message error.

There are a number of interleaving methods that are commercially in use. Compact audio disk (CD) players, as an example, make use of interleaving and redundancy, together with sophisticated EDC algorithms, to recover audio with a typical dynamic range of well over 70 dB. The coding gains provide a minimum of 5 dB with a raw burst error rate of 10 (-3) (as in 10 to the -3 power or 0.001) to gains of 13 dB with raw burst error rates of 10 (-4). These gains produce uncorrectable error rates of 10 (-8) to 10 (-17), respectively [2]. As can be seen, coding gain is not linear with error rates, and errors still exist but at a dramatically reduced rate.

5.3 Parity

Parity, as applied in digital error control, is the logical result of adding binary digits. If the logical sum is zero then this condition is defined as "even parity". When the logical sum is one then this condition is defined as "odd parity." Understanding the parity concept is extremely important since it is the basis of nearly all sophisticated digital error detecting and correcting techniques.

The sums we refer to are from the logical addition of all bits in a message. Say that an incoming message was "10101", like that in Figure 1. From the above discussion, we would determine the parity of this message by adding together the bits and testing the resulting sum.

Before we can proceed, it is important to know how to add with binary numbers. The elementary rules of binary addition are [3]:

$$0 + 0 = 0$$
$$0 + 1 = 1$$
$$1 + 0 = 1$$
$$1 + 1 = 0$$

Any two identical bits produce a zero sum, while any combination otherwise produces a sum value of one. This, by the way, is the truth table for a two-input exclusive-or gate. In general, binary addition is commonly termed "modulo-2" addition. Special note: here is a case were one plus one does not equal two!

Anyway, with this set of rules we can determine the parity of any number of bits. For the given example, the parity is "odd" because

$$1 + 0 + 1 + 0 + 1 = 1$$

where the sum was evaluated to a value of a logical one. Observe that there are always an odd number of ones in "odd" parity, and consequently "even" parity has a even number of ones.

So how is parity applied to error control? A simple technique is to send a message with a known parity. To force a message into a desired parity, one needs to evaluate the parity of the original message first, and then append the resulting bit, often called the parity-bit, to the original message. This has, of course, increased the message by one bit, but now the message is guaranteed to be transmitted with a known parity. In general, if M is a message composed of b-bits such as

$$M = [\ b_1\ b_2\ .\ .\ .\ b_n\ ]$$

then the parity-bit is computed by

$$p = b_1 + b_2 + .\ .\ . + b_n$$

and the parity-corrected message actually transmitted is

$$M = [\ b_1\ b_2\ .\ .\ .\ b_n\ p\ ]$$

Note that the parity-bit was appended to the original message. When the true "p" is appended to M, then M will always have "even" parity. When "p" is complemented (if 0 then 1, or if 1 then 0) then M will have "odd" parity. In the case of our example, these steps are shown to produce:

$$M1 = [\ 10101\ ]$$

$$p = 1+0+1+0+1 = 1$$

$$M2 = [\ 101011\ ]$$

where M1 was the original message and M2 was the parity-corrected message. The M2 message is necessarily one bit longer than the M1 message. This is a penalty since we have started to add overhead, i.e. bits sent that are not the actual message, and overhead reduces the overall message rate.

But the reason for adding a parity-bit to our message was to guarantee message parity. The encoder and decoder were both in aggreement as to the parity of the messages. Thus, if the decoder evaluates a message with a parity different than what was expected, an error can be announced. This idea was the basis for many high-powered error detection and correction techniques.

Obviously, this method alone, although better than nothing, is a weak defense against digital noise. It is quite possible for noise to corrupt the message but retain the original parity, thus giving a false sense of protection. Therefore, more powerful techniques must be considered.

6.0 ADVANCED TOPICS

Section 4.1 alluded to several performance classes of EDC techniques. As it turned out, each class had its advantages and disadvantages. What is one willing to pay for EDC? The addage "you get what you pay for" applies perfectly in this case.

In all cases, one must examine and process the original message, perhaps changing or adding code to the original information. These codes are not unlike the parity-bit we added to our little binary message. But a simple parity-bit may be the least effective code we could generate, next to none at all. If expense and response time were no object, then one would pursue methods that produced the highest gain, i.e. those methods that generated the biggest difference between coded and non-coded Signal-to-Noise levels (coding gain).

This leads to a brief description of "block" and "convolution" type codes. In general, simple block codes provide an effective low-cost EDC solution. They typically can correct one-bit errors, and detect two or more bit errors. Block codes take a fixed bit-size information block and generate a special codeword that is appended to the message. The codeword is usually a parity-like function that uniquely describes the information block. This uniqueness permits effective error detection and single-bit correction. Each block of information is considered independent of preceding data blocks.

Convolution codes differ from block codes in that convolution codes take a stream of information bits and generate a stream of encoded bits by applying feedback (or recursive) equations often called generator polynomials. Unlike block codes, these type of codes require memory of recently processed bits, and so have structures like that of some digital filters.

Concatenated codes are encoding techniques that merge more than one EDC method into an overall error control scheme. These have been found to be highly effective, but necessarily require the highest cost of all. Table 1 provides a short list of some well known coding methods and their respective coding gains.

Communication scientists and information theorists have, over the past thirty years, developed a wide variety of techniques that have application in many different systems. This includes cable system networks, too. Your equipment should incorporate some form of effective EDC, if not then chances are the complaint levels may be excessive. The interested reader is encouraged to investigate this most fascinating field of digital error control.

TABLE 1. A partial list of some EDC codes grouped by performance. The gain is the difference between coded and non-coded Signal-to-Noise levels [1,4].

CODING GAIN	CODES
1-3 dB	Hamming Golay
4-7 dB	BCH Reed-Solomon (RS) Viterbi
+8 dB	RS-Viterbi Fano

Note: Use of redundancy and interleaving in addition to the error control coding significantly increases coding gain.

7.0 SUMMARY

Cable system networks have evolved from television signal distribution systems to multi-service advanced communication systems employing digital remote control at a number of levels in the network. Satellite links have delivered attractive programming to cable operators, with encryption and scrambling equipment providing effective program and revenue containment.

Individual decoder control has blossomed as a de facto standard. Digital computer commands are issued to each or all decoders by inserting this data and other digitized information in the VBI and HBI of the video signal in base-band transparent designs, or on sub-carriers or extended bandwidth channels.

The serious effects of digital data errors demand error control techniques radically different from that offered by classical analog noise control solutions. Significant gains using digital error control methods can be obtained, but at the minimal cost of added complexity.

Redundancy, interleaving and parity were basic concepts upon which elaborate techniques were designed and implemented in most digitally oriented communications equipment found commercially in use today. The box on your TV is not just a decoder, it is truely a marvel in communications technology.

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EFFECTIVE STATUS MONITORING
THROUGH
HIERARCHICAL DISTRIBUTED PROCESSING

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ABSTRACT

As cable systems continue to grow in complexity and length a good status monitoring system capable of reducing down time is a must. Such a system should be able to detect a problem before an outage occures and be expandable to meet the future needs of the system.

As the power of micro computers increases and the cost continues to fall a multiple processor status monitor system becomes a cost effective tool for the system operator. The multiple processor system will decrease detection time while increasing reliability and future expandability.

This paper will disribe the advantages of such a system in detail and try to show what could be done in the near future by using the power of the micro-computer.

INTRODUCTION

Up until recently status monitoring has been a luxury rather than a necessity. Down time has always been a major concern but now with more and more systems caring data the system operator needs to find problems before the outage occurs. Sensors to measure exact levels, voltages and temperature need to be combined with error free data transmission to and from the computer. The operating console needs to be easy to use and the software should be written with future expandability in mind.

By having multiple levels of processing power the data can be concentrated at each level so that the data flow will be minimized at the higher levels (Reference Figure 1). The operator control computer (OCC) is located at the headend or billing office. It collects data from the remote polling controller (RPC) by polling them one at a time. The data is then used for trend analysis and the printing of alarm status. The operator can quickly examine any problem using the user friendly menus.

Communications between the OCC and the RPC's is done using standard RS-232 with data rates of 300 to 9600 baud. Data in both directions is checked using 16 bit cylindrical redundacy checking (CRC-16).

The RPC keeps track of all the data from the remote status modules (RSM) including limits and alarms. In fact, all the operator console would have to normally do would be to issue a "Is there anything wrong" command. The lower level proccessing would take care of polling and limit checking. In this way the operator console (OCC) could use low speed data lines such as phone modems to allow the OCC to be located anywhere. This would also allow the remote polling controller (RPC) to be located at a remote hub site and if multiple hubs existed they could be physically located miles apart.

A typical system would consist of the following:

1) Transponders
2) Remote polling controllers (RPC)
3) Operator command console (OCC)

The following is a description of each level of processing in detail.

TRANSPONDERS

The transponders are located at the device to be monitored. Their job is to carry out commands from the RPC and send back data when instructed to do so. Features to look for in a transponder are:

1) Number of stations that can be addressed.
2) Number of inputs and outputs.
3) Data speed and error checking.
4) Dynamic range of RF modem.
5) Power requirements.
6) Future expandability.

The Jerrold advanced status monitor tranponder is refered to as an RSM or remote status module. It uses a state of the art micro-computer IC that has on board read only memory (ROM), random access memory (RAM), serial port and input/output ports (Reference Figure 2). This is a big advantage because of the space savings and powerful data error checking that can be done.

The number of stations that can be addressed is an important concern. If there are too few addresses then not all devices in the system can be monitored. If there are too many then the response time to find a failure incresses. In a multi-processor enviroment the work load can be divided between several computers. In the Jerrold advanced status monitor we allow 1000 addresses for the transponders. At a data speed of 19.2 Kbits per second and a total transmission word length of 47 bytes this gives a polling time of under 60 seconds. If more stations are needed another remote polling controller can be added. A maxiumin of 16 remote polling controllers can be in one system thus giving a total of 16,000 monitored stations and a maximum response time of under 60 seconds. An example of the advantage of distributed processing would be if the system had 1,600 stations to be monitored. If 16 RPC's were used to distribute the work load and each polled 100 stations, then the response time for a complete system poll would be under 6 seconds.

The RF modem is built into the transponder itself thus allowing installation in either a trunk amp, remote power supply or anywhere on the 2 way cable system. The RF modem is designed with a dynamic range of over 40 db thus allowing it to receive data in very weak signal conditions as found in the case of a failed trunk amp. FM modulation was chosen since it gives a 6db S/N improvement over AM. Data is transfered using standard 8 bit asynchronous format with one start bit, eight data bits and one stop bit with a baud rate of 19.2 Kbits per second.

Error checking on all data to and from the transponder is done by using a 16 bit cylindrical redundacy check (CRC-16). This the the type of error checking done by most of the advanced communication programs and would be extremly difficult to do without the micro-computer.

Power requirements are an important specification to look for in any piece of cable equipment. The micro-computer replaces the function of many IC's and by using CMOS technogoly both current and heat are reduced. In the Jerrold advanced status monitor transponder we were able to keep the power requierment under 150 ma @ 24VDC.

Future expandability is provided by sending a type code along with the data stream. The micro-computer in the transponder then looks at this code to determine what system configurization it is to be used in. We are currently using seven different types leaving 249 additional types to be used in the future.

Additional expandability is provided by an op-code that is sent to the RSM (Reference Figure 3). Op-code zero instructs the RSM to return its analog and digital data while op-code eight instructs it to load limits and alarms. A simple re-programming could be done to add many more commands.

Analog HI and LOW limits are compared in the transponder itself. This saves computer time in the polling computer thus providing a faster polling time.

The computer also controls the return RF level. The RPC measures the return RF level from the RSM and then can command it to increase or decrease its return level. By using the closed loop architecture between the two computers an adjustment free system has been realized that is nearly independent of reverse amplifier set-up gain.

Remote Polling Controller

The remote polling controller has two basic tasks. The first task is to poll the transponders connected to it and store this information in memory. The second task is to receive commands from the operator control console and send back requested information.

The Jerrold advanced status monitor RPC is baised around the IBM PC computer. To be as flexible as possible all of its software is uploaded to it from the operator control console computer thus allowing future software updates with NO hardware changes. Since its software is running out of random access memory no disk drives, keyboard or video monitor are needed for this computer there-by increassing reliability.

To get the maximum polling speed another micro-computer IC is installed on a plug-in card in the remote polling computer. The job of this status monitor interface board is to take data from the RPC and send it in a serial format on a radio frequency to the transponders. Once the RPC sends a command to this board it is free to handle commands from the operator control console and waits for the board to tell it that it's ready. In the Jerrold advanced status monitor there are four levels of processing that the data flows through.

THINGS TO COME

The multiple processor environment frees up each computer to handle a bigger task. I see the day coming when there will be computer controlled stations, not just computer monitored. Imagine a trunk amplifier that all that was necessary to set it up was to turn it on. The micro-processor could measure the pilot levels, control the slope and gain, adjust for outside temperature and send back a report of system flatness at its location. Total amplifier failure could be bypassed and previous amplifier levels increased to compensate for it.

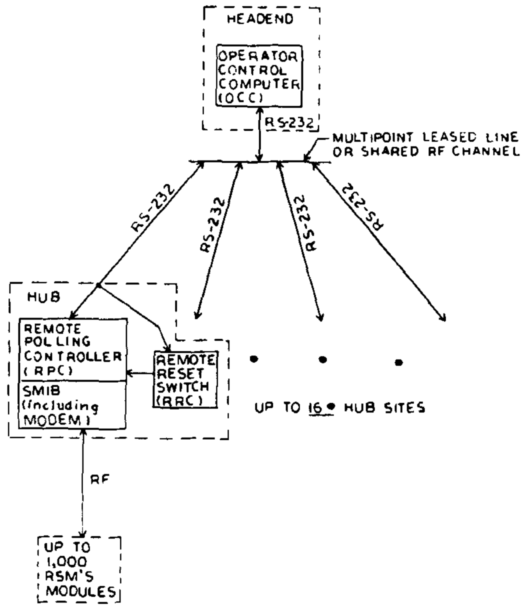

FIGURE 1: SYSTEM DIAGRAM

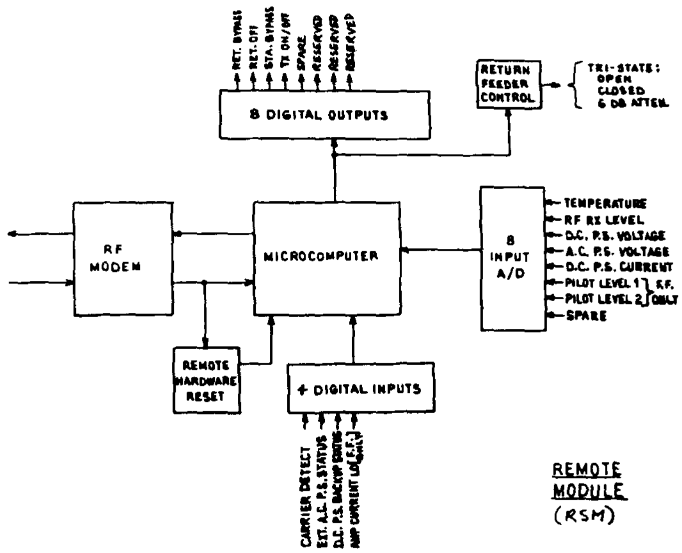

FIGURE 2: REMOTE STATUS MODULE

COMMAND: Return Alarms and Values

OPCODE: HEXØ, BINARY ØØØØ

DESCRIPTION: Report all alarms and all analog and digital values.

F O R W A R D T R A N S M I S S I O N F O R M A T:

4	4	8	16
OP-CODE	ADDRESS		CRC-16 CHECKSUM

4	4	8	8	8	8	8	8
OP-CODE	ADDRESS		ANA-LOG HI ALARMS	ANA-LOG LO ALARMS	DIG-ITAL IN-PUTS	ANA-LOG VALUE 8	ANA-LOG VALUE 7

8	8	8	8	8	8	16
ANALOG VALUE 6	ANALOG VALUE 5	ANA-LOG VALUE 4	ANA-LOG VALUE 3	ANA-LOG VALUE 2	ANA-LOG VALUE 1	CRC-16 CHECKSUM

B I T F O R M A T S:

ANALOG HI ALARMS								ANALOG LO ALARM								DIGITAL INPUTS							
AHA8	AHA7	AHA6	AHA5	AHA4	AHA3	AHA2	AHA1	ALA8	ALA7	ALA6	ALA5	ALA4	ALA3	ALA2	ALA1	DI8	DI7	DI6	DI5	DI4	DI3	DI2	DI1

FIGURE 3

FIELD TESTING OF A DIGITAL AUDIO SYSTEM

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ABSTRACT

Cable operators are currently presented with multiple vendor options when considering the addition of high quality audio services. Initial product selection by the operator will serve to communicate the minimum acceptable functional and performance requirements to manufacturers. System operators are therefore uniquely positioned to demand the best in quality, performance and economy from future audio products. Technical product field testing provides the operator with preliminary information which may be valuable in determining how to invest capital for a new service.

INTRODUCTION

Laboratory testing of a new digital audio system occurred at the ATC R&D facility during the summer of 1985. After the completion of these tests, an engineering field test began and, as of this writing (1/86), is still in progress. The primary purpose of the field test is to evaluate the performance of the system technically. However, it is expected that valuable information from the consumer's perspective will be received from a second phase of the two phase field test.

The system under evaluation was previously described in the NCTA 1985 technical paper titled "A Digital Audio System for CATV Application". The prototype Toshiba system consists of one hundred terminals and one four channel headend. Field trial activities occurred at American CableVision of Thornton, an ATC system in Thornton, Colorado. During the field trial, participants are both friendly and typical subscribers. Audio programming is provided to subscribers from a variety of high quality sources. In general, technical evaluations have provided positive results. Areas of improvement for the current design have been identified with some modifications deemed essential. However, terminal characteristics which relate to operation in a practical cable environment are acceptable.

SYSTEM COMPONENTS

Subscriber Reception/Decoding Equipment

In both the laboratory and field test, the system component which is the primary focus of attention is the in-home DCAT (Digital Cable Audio Terminal) unit. The terminal's primary functions are the tuning and demodulation of QPSK digital DCAT data, separation of demodulated data into audio and control information, and conversion of digital audio data to high quality analog audio signals. The audio signals are compatible with standard auxiliary inputs on existing commercial audio amplifiers. The terminal also maintains internal RAM tables which contain system channelization and subscriber authorization data. A user interface in the form of a front panel keypad allows selection of headend delivered programs if appropriately authorized.

When used with compatible custom headend equipment, the terminal delivers high quality audio in one of two quality modes:

- "Ultra": 96 dB dynamic range (16 bits)
  20 Hz to 20 kHz frequency response
  Greater than 86 dB signal to noise

- "Super": 86 dB dynamic range (14 bits)
  20 Hz to 15 kHz frequency response
  Greater than 76 dB signal to noise

Operation is permitted from 88 to 120 MHz with any single RF channel capable of being positioned within this spectrum with 100 Khz granularity. Each channel may contain either one 16 bit "ultra" stereo program or two 14 bit (companded to 10 bit) "super" stereo programs.

This field test is the first test in the United States of this equipment in an actual cable environment. As a result, some appropriate goals for this test have been verification of initial specifications and evaluation of it's practical application in a typical cable and subscriber environment.

Audio Headend Equipment

The prototype headend equipment used for the initial testing of the DCAT system was designed and constructed by Toshiba. Figure A shows the basic components of the headend equipment and primary cable system interface. The labelled modules shown in the diagram represent one RF channel. All modules are duplicated for the remaining three channels with the exception of the control computer.

The Analog to Digital Converter modules provide an external input interface for connection of the audio programming sources. All inputs are baseband analog audio. The primary functions of this module are filtering and digitization of baseband input audio, generation of subscriber authorization, and serialization of digitized audio data for eventual DCAT transmission frame formatting.

The DCAT Frame Encoder provides two critical functions: the formatting of input serial digitized audio data into a data frame configuration which is compatible with the DCAT in-home terminal, and the insertion of program definition and system channelization data into

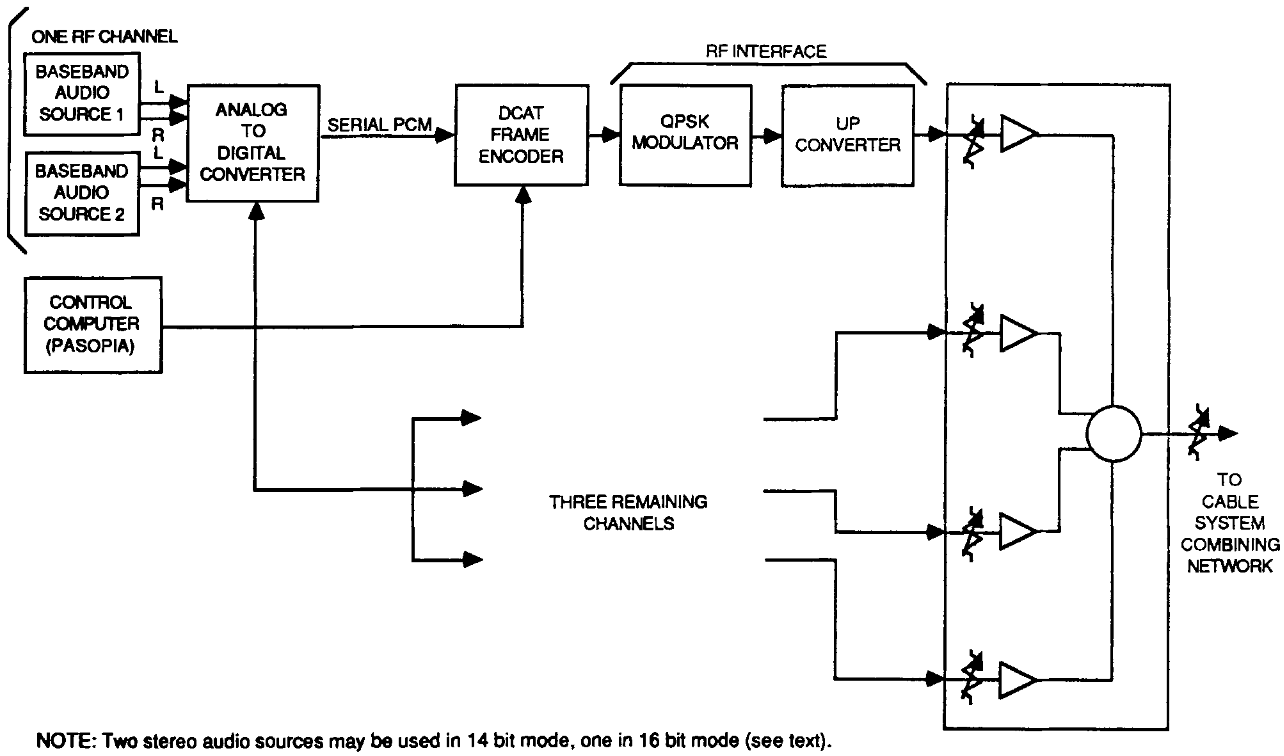


FIGURE A:
FOUR CHANNEL HEADEND FOR TOSHIBA DCAT TERMINALS

the DCAT frame. The Encoder also generates the required error control codes for error detection and correction functions performed by the in-home terminal.

The final encoded baseband bit stream is input to the RF Interface where the digital data is converted to a QPSK (quadrature phase shift keyed) signal and up converted to the final transmission frequencies. At this point, the RF output for each channel is input to a DCAT combining network. The output of this network is input to the cable system's primary combining network.

The control computer provides a user interface for the headend operator which permits definition of program quality options (16 or 14 bit modes), program channelization selections and free tier or encrypted (addressable) modes of operation.

The headend equipment used in this field test is not representative of a final production headend. The headend consists of the same hardware and software which was demonstrated at the Western Cable Show at Anaheim in December 1984.

Audio Programming Sources:

Multiple audio programming sources were used to provide listeners with a sufficient number of alternatives in programming material so as to encourage their participation in the test. (It was intended that subscribers provide ATC technical personnel with descriptions of unusual or improper operating situations which may imply technical problems rather than evaluate the programming material provided by the signal sources.) Additionally, it was desired that experience be gained in connecting headend audio sources to DCAT audio headend equipment in typical CATV situations.

The following audio program sources were used for Phase 1:

A. One Compact Disc (CD) Karaoke player (a CD jukebox which was specially modified by Toshiba for continuous, sequential CD access and play).

B. Audio for MTV, VH-1, HBO and Cinemax.

C. WFMT (satellite delivered "superstation" with classical format).

D. KBCO (an FM broadcaster in Boulder, Colorado featuring unusual and well chosen rock selections, often using CD sources)

All audio source equipment provided analog audio outputs as required for connection to the Toshiba headend equipment.

The following table defines the equipment used to provide each of the audio signals to the Toshiba headend. These sources may be considered to be typical sources in terms of potential interface requirements for future headend equipment.

Source	Equipment
HBO, CINEMAX	M/A-COM Videocipher II
MTV, VH-1	Wegener Dolby Digital Demod (Series 1739)
KBCO	NAD Stereo Tuner
WFMT	Wegener Analog Demod (Series 1620)
CD JUKEBOX	Toshiba/EMI XK-601EMa with custom continuous play modification

System Distribution Equipment

DCAT signals were transmitted on six system trunks. The distribution equipment consisted of Jerrold SJAS-400 trunk amps, SJBN-400 bridger amps and JLE-6-450 line extenders. The longest cascade in the system was "A" trunk which has 25 amps followed by "C" trunk which has 24 amps. The other trunks,B,D,E and F had 15,2,18 and 17 amps, respectively.

The Toshiba headend provided 4 physical (RF) channels for use during the field test. For Phase 1 testing, one channel was configured for the highest quality mode of operation (16 bit, 20 to 20 Khz); the remaining channels were assigned to the lower quality mode (14 bit, 20 to 15 Khz). Operation in the 14 bit mode allows 2 stereo programs of this quality level to exist on one RF channel, effectively doubling the program density relative to the 16 bit mode. The Toshiba CD Jukebox was assigned to the highest quality channel.

The following channel assignments were applicable during Phase 1:

Program	Frequency	Mode	
HBO, CINEMAX	109.2 MHz	14 bit	Stereo
VH-1, MTV	110.6 MHz	14 bit	Stereo
KBCO, WFMT	111.8 MHz	14 bit	Stereo
Jukebox	113.0 MHz	16 bit	Stereo

The first RF channel in the above table (109.2) was spaced 1.4 MHz from the next highest channel (110.6). The remaining 3 channels were separated from each other by 1.2 MHz.

Although the DCAT terminal had a specification of 1.4 MHz for channel spacing, 1.2 MHz spacing was used throughout Phase 1 due to headend limitations.

In Home Configuration

In the Thornton cable system, all friendly subscribers were installed using basically two types of in-home component configurations. Subscribers already had either one or two television sets; the terminal was connected to the system by adding a directional coupler in-line with the appropriate cable. A directional coupler (DC-8) was chosen for terminal feed due to the desire to minimize signal loss to existing television sets and to maximize isolation of the terminal from these sets. The physical configuration for a two-set home is shown in Figure B. For this configuration, isolation averaged 28.8 dB thru the splitter/DC path (20 dB/8.8 dB) and in excess of 30 dB between the DC output and the terminal feed leg. This ensured sufficient margin to prevent spurious output interference to either the terminal from a television or vice versa.

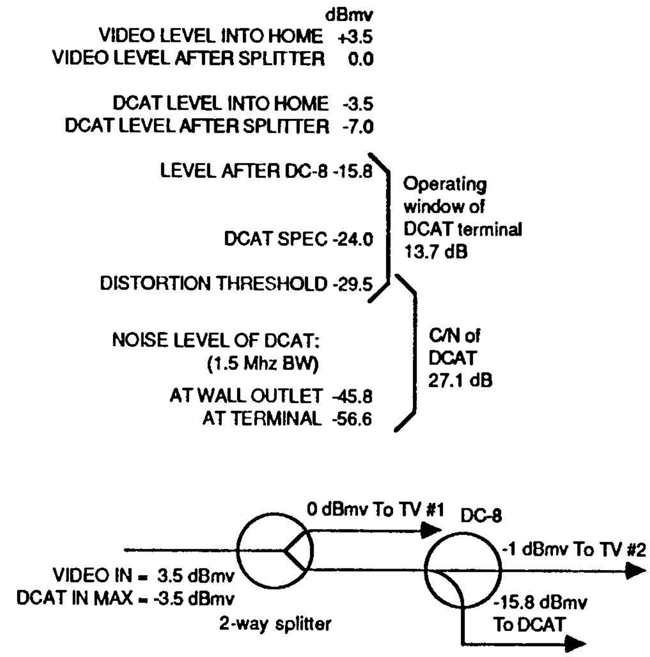


FIGURE B
TWO-SET IN-HOME CONFIGURATION

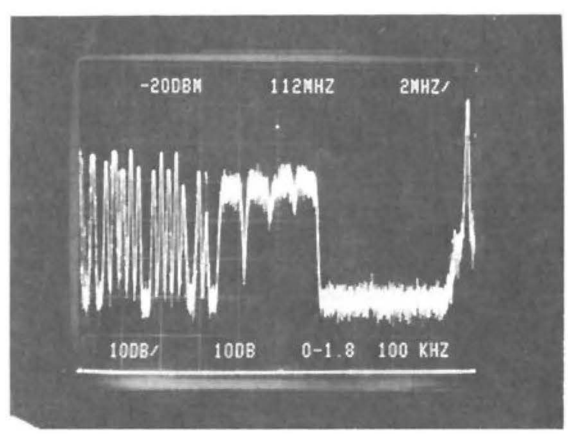
Use of a directional coupler minimized video signal loss to approximately 1 dB.

The one and two-set configurations are considered to be typical for most homes which would eventually receive service. Based on these assumptions, it was possible to define a practical operating window with respect to transmitted and received DCAT signal levels.

TEST RESULTS

Signal Degradation After Cascades

Prior to connecting the friendly DCAT subscribers to the system, the transmitted DCAT signals were visually inspected at various points on selected trunks. A photo of the signals at the end of the "C" trunk (24 amps deep) is shown in figure C.



The effect of the system trunk cable and amplification equipment was minimal. Terminals tested at these positions operated normally. A test point on the terminal PC board permitted measurement of the number of bit errors which were not correctable by the single error correcting, double error detecting BCH code used in this system. No significant increase in uncorrectable errors was detected relative to previous lab measurements.

Operating Window

Practical DCAT system operation when operating in the A-1 and A-2 channels as in this field test was defined based on the following criteria and considerations:

A. Upper limit:

1. FCC restrictions for operation on aeronautical navigation frequencies.

2. The requirement to remain within existing system design guidelines regarding maximum power available from system distribution amplifiers within the spectrum where DCAT operation was intended.

B. Lower limit:

1. The presence of audible distortion in the received audio output caused by limitations in the error correction or digital audio interpolation capability of the terminal. (The primary causes of this effect are excessively low signal input levels or exceeding the carrier to noise capability of the terminal).

Details on Operating Window Estimate: UPPER LIMIT

Signal level restrictions in the A-1 and A-2 bands required that signals be operated below 10^{-5} watts (28.75 dBmv) unless the FCC is notified. American Cablevision of Thornton operates channel A at approximately 38.5 dBmv and provides the FCC with this information on an annual basis. An additional 3 to 4 dB of level fluctuation is expected due to equalizer settings and temperature. For operation during the field test, DCAT signals were transmitted at a carrier level 15 dB below the video carrier of channel A (23.5 dBmv plus temperature tolerances). At this level, signal levels are well below the specified FCC threshold for notification. Future FCC regulations will require that the average level of signals transmitted in the A-1 and A-2 bands not exceed 38.75 dBmv averaged over any 160 microsecond period within a 25 kHz bandwidth at any point in a cable plant (unless the FCC is notified). According to the update to FCC Notice 21006 which describes the above requirements, this limitation will not exist for operation in the 88 to 108 MHz spectrum region.

For the DCAT system, the highest level which would be transmitted within a 25 Khz window occurs when modulation is removed from the transmitted signal. The unmodulated carrier peaks at the center frequency of what was previously the QPSK signal. This situation, in practice, is quite possible, requiring only a failure in the portion of the headend equipment which generates the DCAT bit stream. Potential users of the DCAT system in the A-1 and A-2 channel slots should be aware of these limitations and notification requirements.

A major factor with respect to introducing new signals into a cable system is the requirement to prevent excessive loading of the system amplifiers due to exceeding system design limitations. These limits are based on the ratings of the particular amplifiers in use and on the assumption that video signals are carried throughout the cable spectrum.

Using the bandwidth of a normal 6 MHz video (and in-band audio) signal as the reference, and assuming that DCAT signals are positioned maximally adjacent at 1.2 MHz spacing within this 6 MHz window, 10 log (BW DCAT/BW Video) = -7 dB states that operation of every DCAT signal at 7 dB below video maximum will result in operation at the design specification of the system.

If the minimum video level present at the subscriber television input is zero dBmv, as required by the FCC, then the highest level allowable for DCAT signals based on this limit and the desire to retrofit DCAT into existing systems is -7 dBmv. Any additional signal level at the wall provides additional margin. Using 3.5 dBmv as a minimum video level in a practical system, DCAT signals would arrive at a splitter at -3.5 dBmv and be reduced to approximately -15.8 dBmv by the splitter (3.5 dB loss) and the DC-8 (8.8 dB loss) for the two set configuration. Therefore, a practical upper level limit which recognizes the design limits for the system would be -15.8 dBmv for Thornton.

Operation during Phase 1, however, was done at a level of 15 dB below channel A video (-24 dBmv after two-set losses). This placed DCAT signals at the same amplitude as existing FM carriers and resulted in the received signal levels being at the threshold of the DCAT receiver dynamic range specification (-24 dBmv). These levels provided good results throughout the test, since the terminal's actual lower limit was significantly below this operating level.

Details on Operating Window: LOWER LIMIT

Determination of the practical lower operating limit was done by measuring the absolute peak level of a DCAT signal at the RF input to the terminal at trunk taps while the amplitude of the signal was reduced at the headend. A measurement of received signal was made at a level just prior to detection of audible clicks in the audio output of the terminal. Additionally, the background noise level was measured for carrier to noise performance evaluation. Independent measurements were performed at the end of three separate trunks in the system. The following were the results:

Trunk	Cascade Length	Noise Level (dBmv)	Signal Threshold (dBmv)	Effective C/N (dB)
A	25	-45	-29.5	-15.5
C	24	-45	-29.5	-15.5
E	18	-50	-35.5	-15.5

Note: All DCAT signals were reduced simultaneously with no measurable deviation in signal level between adjacent channel peak amplitudes.

Based on these results, it appeared that the threshold was reached due to C/N limitations of the terminal. In an attempt to confirm this point further, and to gain additional information regarding the degree of uniformity in C/N performance throughout the specified dynamic range window (+5 to -24 dBmv), additional tests were conducted in the Thornton headend. Data was taken on 3 different terminals where C/N was measured as a function of input signal level. The input signal was reduced in 3 dB steps from +5 dBmv and noise increased to the distortion threshold. A C/N measurement was taken at each point until a limit was reached where no attainable C/N prevented objectionable audible clicks.

Two of the terminals provided very consistent results: the C/N requirements remained within 1 dB with an input signal range of +5 to -33 dBmv. The C/N requirement window throughout this input range was from 16 to 17 dB for the first terminal and from 15 to 16 dB on the second. Between -33 and -37 dBmv the C/N required was 25 dB; at -34 dBmv, C/N required was 28 dB with the absolute threshold at -37 dBmv.

When referring to Figure B note that the "C/N of DCAT" is the effective C/N when the input signal to the terminal is -29.5 dBmv at the Thornton cable system. Since the system noise is reduced noticeably by the DC-8, additional margin with respect to C/N exists when the terminal is operated in this configuration based on the 3 terminal test results summarized above. Of course, operation in this signal level region (below -24 dBmv) is not recommended since the inclusion of sensibly defined operating margins is necessary to ensure continued stable operation under adverse system operating conditions. Toshiba's specification of -24 dBmv provides a desirable level of safety. The C/N spec, measured in a 1.5 MHz noise bandwidth is 28 dB and includes approximately 10 dB of margin from various sources.

Level Deviation Between Adjacent DCAT Carriers

A test of the effect of signal level variation of the center DCAT carrier of the triplet with respect to the adjacent carriers was performed in the Thornton headend. This test was similar to laboratory tests with respect to the test environment since the RF signals were not received by a terminal connected to a system trunk, feeder or tap. The test was performed with 1.2 MHz spacing between the 3 RF channels.

The center channel signal level was reduced in 1 dB steps from the 2 adjacent channels which were adjusted to identical levels. No noticeable effect to output audio was detected until the level of the center channel was reduced to 3 dB below the adjacent channel reference. At this point, audible clicks were clearly heard at the output of the terminal and the BCH uncorrectable error rate increased significantly. It is clear from this test that the terminal is sensitive to these level differences, as indicated by a terminal specification published by Toshiba defining 3 dB as the maximum deviation.

It is important to consider that this test was performed at 1.2 MHz channel spacing due to the headend configuration. The deviation specification is applicable to 1.4 MHz spacing. It is expected that this characteristic of the terminal receiver would improve if the spacing were increased to 1.4 MHz.

Testing was not performed to determine the effect of level deviations between non-adjacent channels.

Use of Encryption

After the primary system testing was completed, all channels were switched from non-encrypted to encrypted (tiered) mode. All channels were assigned the same tier. Operation in this mode for a period of 8 weeks resulted in no negative feedback from cable system personnel or subscribers. It was necessary to individually address each terminal from the headend to activate the encrypted service. This field test activity in addition to laboratory testing has empirically confirmed the functionality of the DCAT encryption technique and system implementation.

Interference Issues

DCAT to Normal Cable Operations

Prior to applying DCAT RF to Thornton system trunks, existing video and audio signals were examined for future reference. After applying RF, there were no reports of interference from any of the Thornton technical personnel. System video and audio signals were again inspected with no evidence of interaction with any of the four DCAT RF signals.

Normal Cable Operations to DCAT

--- High Level Sweeps

The Thornton cable system uses a high level sweep for system analysis. The system in use is a Wavetek 1855/65, which sweeps from 1 to 400 MHz in less than 3 milliseconds at a level of 20 dB above the video carriers. The repetition rate used is from 1 to 25 seconds during this operation. Each sweep generates an audible click at the terminal audio output. Based on the characteristics of the sweep, it is possible that 2 subframes of DCAT information could be destroyed for each sweep (approximately 10 microseconds per RF channel at 1.4 MHz). Although the click is not particularly loud to the listener, it is not known whether this event could cause damage to a subscriber's stereo system. A system operator considering the use of this system should assume that the potential for damage exists, and plan on providing a notch filter at the sweeper output.

--- Low Level Sweeps

The pertinent specification for the DCAT terminal with respect to susceptibility to interference from a low level sweep system is the desired to undesired ratio. To prevent interference to transmitted DCAT signals it would be required that the RMS level of the sweep output signal be at least 14 dB below the peak level of the DCAT signals.

Low level sweeps are most often operated at levels of 10 to 20 dB below system video carriers. DCAT signals may be operated as low as 15 dB below video and an additional 14 dB is required to satisfy the D/U requirements of the terminal. Under these conditions interference will occur. It is reasonable to expect that the effect of the interference would be similar to that experienced under high level sweep conditions.

Systems employing low level sweeps with output levels greater than the D/U specification below DCAT (plus reasonable margin) should plan on the use of notch filtering or similar solution to prevent interference.

--- Premium Service Traps

Thornton cable system uses Channels A and C for premium video services. When DCAT terminals were initially installed at some subscriber sites, the effect of two types of traps in use in the system to prevent unauthorized reception were observed on DCAT signals. One type of trap is used to prevent reception of a single service in channel A or C while the other type is used to eliminate channels A, B and C. The attenuation of the multichannel trap from 110 to 120 MHz is quite severe, with 2 dB attenuation at 110 MHz to 40 dB at 120 MHz. The single channel trap attenuation ranges from 1 dB at 110 MHz to 3 dB at 115 MHz with the attenuation increased to 20 dB at 120 MHz.

The terminal specification for level deviation between DCAT carriers does not permit adjacent DCAT channel level deviations from exceeding 3 dB or in-band level deviations between non-adjacent channels in excess of 6 dB.

Assuming this situation is common in existing cable systems, this specification introduces restrictions on cable operators regarding reliable terminal operation and use of cost efficient deauthorization components in non-addressable systems. The operator who is faced with this situation will be required to engage in careful spectrum planning and system analysis before initiating subscriber service. Fortunately, the effect of the traps used in the Thornton system between 88 and 108 MHz was negligible.

Installer Feedback

A questionnaire and information summary sheet was completed for 22 of the 23 friendly subscribers at the time of initial DCAT installation.

The requested information included a description of the customers stereo system, the in-home installation and the general environment in which the terminal was installed. The subscriber's initial comments concerning the installation, terminal or service were also requested.

Very few trends could be determined from the data on stereo system type. A wide range of manufacturers and qualities were represented. The most common type of system was the "rack" system from labels like J.C. Penney, Fisher, and Zenith. None of the subscribers owned Compact Disc players. A few subscribers had no stereo system, using headphones only on the terminal.

Most installations had relatively short (less than 5 ft.) cable runs from the wall plate to the TV and stereo. In one installation the stereo was located in a basement room 30 feet from the nearest cable outlet.

No problems were reported with heat or interference to or from the DCAT unit, although some subscribers mentioned that the terminal remained hotter than expected during power off periods. This is not unusual since the terminal electronics remain active even after the ON/OFF key is pressed. This maintains the internal RAM for previous authorization and channelization data and allows reception of new data to modify previous information.

As might be expected, the most common comment was good sound quality. Also common were requests for remote control units and positive comments regarding the terminal's appearance. Channel tracking and matching channel numbers for video simulcasts were also stated as desirable. A few commented immediately that they would prefer additional program variety. Some subscribers were very pleased with the terminal's ease of use, and suggested a convenience AC outlet on the terminal back panel. The lack of AC outlets was a common problem during the installations.

Subscriber Feedback

After the friendly subscribers had their service in place for approximately four weeks, all were requested to return completed questionnaires regarding their impressions of the service and terminal equipment. Most subscribers commented very positively on the audio quality. The same comments stated on the installation report were restated by additional subscribers after receiving the service. Several subscribers mentioned that the Compact Disc channel seemed to be lower in volume than the others; perhaps this is due to an unfamiliarity with the wide dynamic range of Compact Disc sources. Several of the other sources used in the test were heavily compressed and thus, on the average, sounded much louder as channels were rapidly scanned.

Measurement Techniques

Spectrum Analyzer

To accurately describe the level characteristics of a DCAT signal, the peak unmodulated carrier level must be defined. However, as terminal installations progress, it is undesirable to interrupt previously installed subscribers' service by removing modulation for a measurement. Therefore, amplitude measurements were performed on the actual modulated signals and a calibration factor applied to normalize to the unmodulated carrier level reference.

The spectrum analyzer used for most of the measurements was a Hewlett Packard 8558B. After modulation is applied to the zero dB peak unmodulated DCAT signal, the signal was measured using the HP Spectrum Analyzer. The following results were obtained:

Bandwidth	Level
1 MHz	-4 dBmv
300 kHz	-9 dBmv
100 kHz	-14 dBmv

There was a 4 dB difference between the zero dBmv peak level of the unmodulated signal and the same signal within a 1 MHz window after modulation was applied.

Bit Error Rate

Toshiba has specified a bit error rate (BER) of 3 x 10^{-4} as the transmission link bit error limit for satisfactory reception of high quality audio as specified for the DCAT terminal. This BER figure is the absolute reference for defining thresholds for a number of different technical specifications (for example: Carrier to Noise Ratio, Desired to Undesired Ratio, Level deviation between RF channels, etc.).

Although the BER specification provides a technically accurate yardstick for defining many terminal specifications, operation at the specified limit consistently resulted in acceptable performance. As a result, all tested terminals met published specifications, however, very little was learned about the absolute limits of various specification parameters on a more subjective level. For this reason, test thresholds were established in a manner which describes the effect of unsatisfactory system operation to the end user. As each specification parameter was varied towards its most undesirable extreme, (while other parameters were maintained at "normal" settings), a common result occurs in the audio output regardless of which parameter is being varied. As a result of exceeding the error correction capability of the DCAT BCH error correction code and audio interpolation capability of the terminal logic, audible clicks due to an excessive number of uncorrectable bit errors in the received data stream are heard at the audio output. The click rate changes from effectively zero per second to thousands per second (audibly resembling white noise) very quickly for a given parameter range change. This result was also reasonably independent of the parameter under examination. Typically, these two extremes would be seen within a 1 to 3 dB window. The limits for the various specifications were determined by listening for clicks to just be detectable in headphones (with no audio programming) at a very low repetition rate; additional change in the parameter would result in the presence of noise (clicks) which, in our listener's judgement, would be objectionable to a typical subscriber.

The method described above is not intended as one which would replace measurements based on BER, but rather one which provides additional information which is practically useable for quantifying specific DCAT terminal parameter thresholds in a realistic cable environment.

Summary

During Phase 1 of the Engineering Field Test, 23 terminals were installed in the Thornton system. All terminals but one operated normally.

The friendly subscribers who received the service were very pleased with the quality of audio although only one of the seven programs was truly from a high quality source (the Toshiba/EMI CD Jukebox). Other subscriber feedback and suggestions consisted of comments regarding terminal appearance, the desire for remote control, matching channel numbers for video simulcasts and the need for greater variety in audio programming.

It has been determined that the terminal is susceptible to interference from both the low and high level sweep systems commonly used in current cable systems. This is primarily due to the low levels at which DCAT operates. Therefore, it will be required for cable operators using DCAT to include a notch filter at their sweeper output to prevent the occurrence of the low volume click heard by terminal users as the sweeper is active.

Cable systems which have assigned Channels A, B, or C for their premium video services and use negative traps to prevent reception will need to exercise care in providing DCAT service to subscribers who are not authorized for these video channels. This caution applies primarily for systems who transmit DCAT in the upper portion of the 88 to 120 MHz band.

An operating window with respect to input signal level was established based on FCC restrictions, system design constraints and minimum useable signal limitations of the terminal. With the in-home configurations used in Thornton cable system, practically useable windows of approximately 14 dB and 17 dB were determined for two-set and one-set configurations, respectively. These windows extend beyond the low end dynamic range specification published for the terminal by 5.5 dB.

The technical testing which is described in this paper is a small subset of the testing performed to date. The detailed technical testing was done during Phase 1 of the test. The second and last phase of the field test, now in progress, is directed toward evaluating consumer reactions to both the DCAT system and additional premium audio programming sources. Information concerning consumer response to the second phase will be available after completion of focus group activity and data compilation.

HARD ENCRYPTED VIDEO AND AUDIO TELEVISION SYSTEM

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Joseph B. Glaab
John T. Griffin

GENERAL INSTRUMENT CORPORATION

There are many considerations involved in the design of a truly secure scrambled television signal. In the encoded mode, recognition of any portion of the original video and audio signals must be obliterated by the scrambling method. The recovery of both these signals must be protected by ecryption techniques developed within a robust transmission system. The circuitry to reconstruct the signals must be reliable and consistent; and its cost must be in line with the benefit. Above all, the quality of the descrambled signals must match the original. We are confident that we have achieved these goals. In the following paragraphs we will discuss the problem areas and our solutions.

Development work on this system started in the second quarter of 1983. The choice of scrambling and descrambling a baseband signal was obvious for several reasons. Signal processing techniques were well understood; both AM and FM systems could be used for transmission; and the ability to transfer from a satellite system to a CATV or MATV system without descrambling was inherent. A modified NTSC format was chosen to stay within the six MHZ bandwidth needed for cable and to keep device costs at a minimum. From the start, highly integrated VLSI circuits were the only choice for the final product. The plan required a minimum of two audio channels and an address/authorization scheme to serve sixteen million subscribers.

All of this information was to be in a digital format. For audio, the Dolby adaptive delta modulation system was chosen because of its proven high performance at moderate bit rates. To assure a robust system forward error correction was included; for security the audio bits were encrypted.

The first test at transmission of this baseband signal used frequency modulation simulating a satellite service. The digital audio and address information modulated a 6.2 MHZ subcarrier as QPSK. The subcarrier became part of the baseband which then frequency modulated a 70 MHZ exciter. Results were very poor. The power required for satisfactory performance of the information on the subcarrier at low carrier-to-noise worsened the threshold level of video by 2.5 db. This was unacceptable. Separately we experimented with a line rotation form of video scrambling and were reasonably successful in descrambling it. It was decided to reformat the audio channels and the address/authorization data to fit within the video signal. Making use of all the horizontal intervals was required; the information content we needed greatly exceeded the time available in the vertical interval. The vertical interval is used for synchronization, AGC for AM systems, and for level references. All information carried in the VBI needed for proper system operation is contained in the first nine lines leaving all remaining lines to be used by the system operator for any service he chooses - Teletext is an obvious option. System tests using this approach were extremely successful. There was no loss of video power since no subcarriers are needed. In fact, the lack of subcarriers and synchronizing pulses improves the carrier-to-noise subjective threshold by one to two db compared to standard NTSC.

With the background established, the following detail is presented.

VIDEO SCRAMBLING

A line splice and section rotation system was used. The system allows for a single video line to be spliced at any one of more than one-hundred locations linearly spaced along the line.

Figure 1 shows an example of the method used.

To accomplish this, the video is processed through an analog to digital converter. The digital samples are stored in a high speed RAM capable of one video line of memory. The splice point is determined from a synchronous stream cipher decryptor using non-linear sequential logic. In effect, the splice point is chosen from a random bit stream in the encryption circuit which is synchronous with the decryptor at the receive end of the system. A time varying encryption is achieved by establishing a new encryptor seed every frame. The stored digital samples are taken from the memory starting at the splice point to the end of the stored line and then, from the start of the line to the splice point. This sequence is passed through a digital to analog converter for transmission. The transmission can be for many services: satellite, cable, microwave, MMDS. At the receive site, after demodulation, the process is reversed.

The scrambled baseband signal goes through an analog to digital converter and is stored in a high speed RAM. The original splice location is known at the receive site via the synchronous encryption stream. The memory location for the start of the line is the complement of this number. As an example,

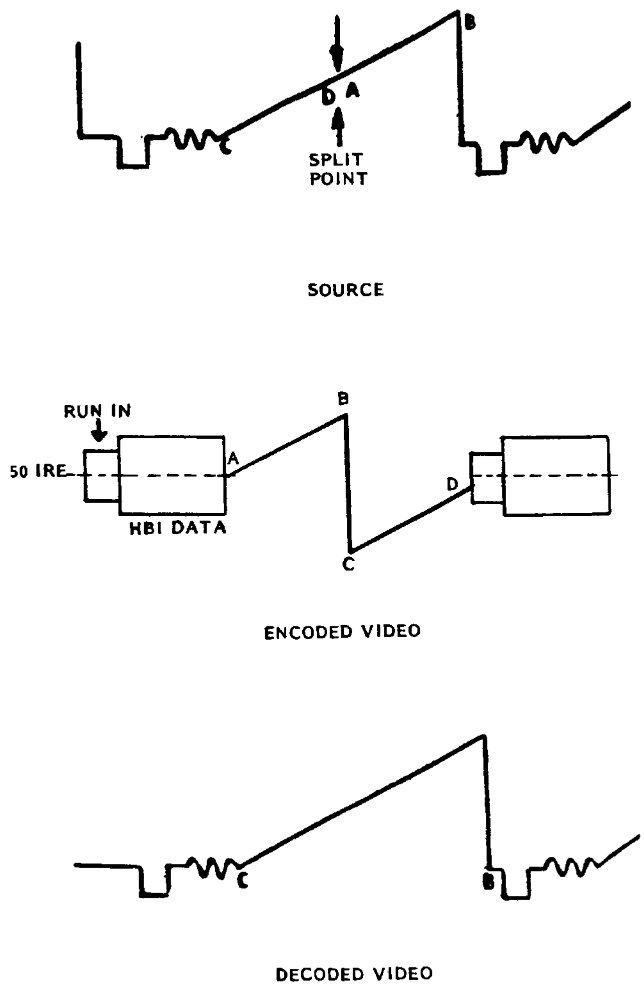


FIGURE 1

there are about 752 memory locations for the active video portion of a line. If the splice were taken one quarter of the way across the line at location 188 then the start of the line would be its complement at location 564 (752-188). The digital information is then taken out of memory beginning at this location and the line is reconstructed to its original form. If the subscriber is authorized to receive programs, the signal is passed through a digital to analog converter for presentation at the video output. In actual practice, the complement algorithm is used at the transmitter to allow for a less complex recovery at the descrambler.

THE HORIZONTAL INTERVAL

It is important for this system that the video signal comply with the EIA Standard RS170A color television standards. To assure this, it is recommended that the source video be processed through a frame synchronizer. A phase locked loop circuit senses the color burst at the video input port of the scrambler. All timing for this system is derived from this reference. The horizontal blanking interval from the source video is stripped clean of sync and color burst. The interval is reconstructed to include digital information starting with a 16 bit run-in code plus 66 bits representing two digital audio channels, address information and data. This interval is referenced to a 50 IRE level. Included in the 66 bits are two interleaved "2 for 3" forward error correctors. We use two level data. The combination results in a very robust transmission system; error free until very low carrier-to-noise ratio are reached. The remaining 44 bits serve the following functions:

13	right audio	Dolby
13	left audio	Dolby
1	step size	(audio)
1	slope	(audio)
8	address authorization	
1	encryptor seed	
1	video invert key	
6	data - (or 2 on-screen display and 4 data)	

The 26 audio bits are encrypted. The 8 address bits per horizontal is equivalent to a 126 K bits/sec rate or a cycle rate of 2.7 million subscribers per hour.

At the receive site the information in the horizontal interval is processed and the horizontal interval is reconstructed with clean sync and color burst to the RS170A specification. The same is true of the vertical interval. These clean synchronizing signals maintain the video in stable lock down to levels of zero db carrier-to-noise. The audio will show distortion at about 5 to 6 db carrier-to-noise but is intelligible to 4 db. The complete descrambler consists of four major integrated circuits: a custom codec; a custom video processor; a control microprocessor with peripheral; and the audio digital to analog chip.

Other important circuits included in the design are:

1) A video AGC.

2) A clamp circuit.

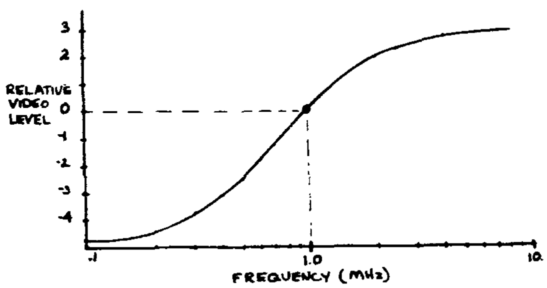
3) A line tilt correction circuit.

The AGC circuit will maintain an accurate one volt peak-to-peak video output signal for ± 3 db variation of the input. This will compensate for varying deviations in FM systems and for sloppy R.F. AGC's in AM systems.

Line tilt is the nemesis of line rotation systems. Experience with both FM and AM tests indicate that this is not a problem for our systems. We attribute this benefit to the format we use in the horizontal interval where the information is centered around the 50 IRE level thereby maintaining an average level across the complete line scan. Nevertheless, we have incorporated a line tilt correction circuit for insurance.

PRE-EMPHASIS/DE-EMPHASIS

For satellite transmission, the format of the scrambled signal allowed for optimization of the pre-emphasis and de-emphasis circuits. After extensive calculation and subjective tests we established that the curve presented in Figure 2 gave a high quality picture for a clear sky condition while it enhanced the bit error rate and gave a significant subjective improvement at low carrier-to-noise levels. Subjectively, it greatly reduces the size of the comet tails caused by impulse noise.



SUMMARY

The techniques discussed result in a practical cost effective scrambling system which features hard encrypted video with hard encrypted stereo audio to insure longevity. The two level, forward error corrected data assures a robust system operating down to low carrier-to-noise ratios. The reconstructed picture is a replica of the original at normal operating levels. It is a baseband system proven in both the FM and AM transmission modes. The line rotation method of video scrambling maintains a very secure signal even in the presence of sync reinsertion defeat mechanisms and digital television chip sets. The use of digital processing methods avoids distortions inherent in analog techniques. The format used allows for special pre and de-emphasis circuits which are optimized to minimize bit error rates and improve the subjective effect of impulse noise. The work effort has met all the goals required for an excellent operating system.

NEW APPROACHES TO SECURING BASIC SERVICES

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ABSTRACT

The shift towards increased revenue generation from basic services (and a corresponding decrease in multi-tier pay revenues) strengthens the need for means to protect those basic services from signal piracy. In the past, scrambling and addressability have been used primarily to protect pay services. Now there is clearly a need for a cost effective method to secure basic channels without rendering existing equipment, especially plain converters, obsolete.

This paper discusses converter compatible solutions to the problem, and describes two specific examples, each of which is capable of being overlaid on an existing system already equipped with converters.

The more secure of the approaches described applies encryption technology to provide a very high degree of security. The other approach is an add-on decoder, examples of which have been available for some time.

INTRODUCTION

Signal security techniques, as applied in cable today, are designed primarily to control the delivery of pay services and to protect revenues. Addressable methods have been introduced to enhance Pay TV operations by making the changing of subscription packages less costly to the operator and more convenient to the subscriber. Addressability is almost a pre-requisite for most forms of PPV. Security in scrambled signals has been enhanced by the use of addressability for delivery of decryption keys.

While it is true that a few cable systems scramble basic service channels, the fact is that encoding of television signals has been directed primarily at pay services. Yet the greater part of cable systems' revenues in 1986 are projected to come from basic subscriptions, and in future years the percentage of income from basic service is expected to increase. Most cable operators admit to some degree of theft of basic service, but few have taken steps to make "basic" signals more secure.

Some pay program material has to be scrambled for obvious reasons. And yes, of course it's simplest to deliver basic programs in the clear, either directly to the television receiver or through an inexpensive converter. However, there can be some interesting challenges for cross-innovation in security methods.

In an existing addressable system it is possible to scramble some or all of the basic channels in the same manner as pay channels. However this means supplying converter/decoders (with their attendant capital costs) to all subscribers, which can place a greater burden on the security of older and less sophisticated scrambling techniques.

Most cable subscribers today are supplied with non-addressable converters of either the programmable (converter-decoder) variety, or non-programmable (plain-vanilla) type. This paper focusses on methods to secure basic services in systems, which today are non-addressable, without rendering the non-addressable converters obsolete.

Functional Requirements

Before discussing the details and merits of specific approaches, it is as well to review some observations regarding "basic" requirements.

- Security -- As the value of the entertainment product continues to increase so will the ingenuity and determination of pirates. Defeating secured "Basic" as well as scrambled "Pay" could be looked upon as twice as rewarding by the pirate.
- Compatibility -- A successful approach should not obsolete existing subscriber terminal equipment.
- Cost -- No technique will be acceptable unless there is a financial pay-off.
- Addressing -- Individual device control is a necessary component of a secure system. However the multi-tier/multi-function controls, usually incorporated into addressable pay systems, are not necessary for basic services.

Two Proposed Methods

In order to illustrate the possibilities of using Pay TV security techniques to protect basic services, two methods will be outlined having in common the use of an addressable device located on the subscribers premises, inter-faced with an existing converter (or non-addressable converter/decoder). There are significant differences between the two approaches related to:

- o adaptability to other uses
- o security

Post-Converter Addressable Decoder

Devices of this kind have been offered for several years by a number of manufacturers of addressable systems. These devices have been marketed primarily for the addition of pay services to systems equipped with non-decoder type converters. Usually they have been designed for system compatibility with converter/decoders designed to decode the same scrambled signals.

A representative block diagram (Fig. 1) is shown of one of these devices (OAK TCM-1) which employs out-of-band addressing. The decoder is equipped with four connectors. The signal from the drop cable loops through the decoder to permit access to the out-of-band FSK addressing channel, and is connected to the converter input. After channel selection, the converter output signal loops again through the decoder in order to accomplish program tag recognition and decoding. The decoder output is connected to the television receiver.

The FSK receiver, similar to that used in other addressable devices, extracts serial addressing control data. The control data contains, in decoder specific messages, the identity of authorized program levels which are stored in the decoder. The output signal of the converter passes through the decoder tag detection circuit. If the selected channel is scrambled, the decoder automatically extracts program level information from the tag signals which are transmitted in the vertical blanking interval. Control circuits compare the tag levels with stored authorized program levels, and if there is a match, activate the decoding circuit. The TCM-1 uses the same dual-mode sine-wave sync suppressed scrambling as OAK's Total Control system.

This type of decoder can be used in a system presently employing a mixture of plain converters and converter/decoders (either addressable or non-addressable) to permit scrambling of all channels, including, of course, basic channels. Any scheme involving encoding of basic channels naturally requires all basic subscribers in the system (or section of the system in which scrambling is employed) to be provided with appropriate decoding devices.

Once installed, the same decoder can be used to extend Pay coverage without additional investment in converter/decoders.

As the decoder utilizes signals which have already passed through a converter, particular attention must be paid in this type of decoder to the effect of converter fine tuning. In the device described, frequency sensitive portions of the decoding detection and tag detection circuits operate at a special intermediate frequency. AFC is used to maintain accurate frequency control of this IF. The decoder is designed to be system compatible with the addressing commands of its converter/decoder counterpart.

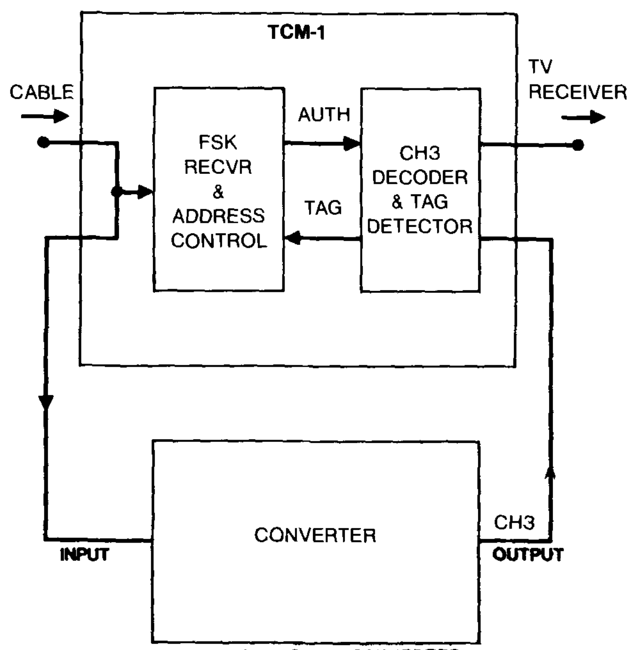

FIG. 1. POST-CONVERTER ADDRESSABLE VIDEO DECODER

Devices of this type are relatively inexpensive (approximately one half the cost of a converter decoder), and are already developed and available. They employ, however, relatively unsophisticated analog scrambling.

Post-Converter Audio Restorer

This section describes a concept, not a product already developed for low cost manufacture.

Security of basic channels is achieved by digital encoding and encrypting the audio portions of each channel for transmission through the cable system in portion of the cable spectrum dedicated to the high speed data transmission of audio (for example a single 6 MHz channel could easily carry 10 stereo channels).

Each controlled television channel is transmitted with clear video but with no analog audio modulation. Instead a tag signal, identifying the channel, is transmitted on the sound carrier.

The equipment provided to the subscriber is connected in the configuration shown in Fig. 2. Again a four connector device is used. The cable signal loops through the decoder allowing the high speed program-audio data to be extracted. The high speed data channel comprises digital encryupted audio, error protection, and control signals.

After television program selection by the converter, the signal passes to the tag detector section of the decoder (Fig. 3). If the channel selected is "tagged," the decoder's tag receiver identifies the tag signal, and seeks a matching digitized audio signal from the receiver of high speed data by control of the demultiplexer (DEMUX).

The audio data is decrypted and converted to analog audio in the DECRYPTER/DAC circuit. It then modulates a Voltage Controlled Oscillator (VCO) used to generate a restored audio carrier.

The signal from the converter is converted to an IF, passes through a filter to remove the sound carrier transmitted through the cable system, and is recombined with the restored audio carrier. Precise phase lock loop techniques are used in the frequency conversion and VCO circuits to assure maintenance of intercarrier frequency accuracy and to minimize incidental FM noise.

As shown the signal passed to the television receiver is a conventional monaural signal, however this scheme is readily extendable to BTSC (MTS) audio.

The concept described here is based on the encryption concepts already employed in the SIGMA product and has the potential to be extremely secure. It is compatible with existing converters and can be used to supplement the security of a wide variety of existing analog scrambling techniques.

This device also is estimated to be approximately one-half the cost of a new converter/decoder of similar security.

The principle can be extended to use without a converter. Used with an IS-15 compatible receiver, a device of this kind could recognize tag information in the broadband IS-15 audio output, and supply audio derived from the high speed data stream directly to the television receiver.

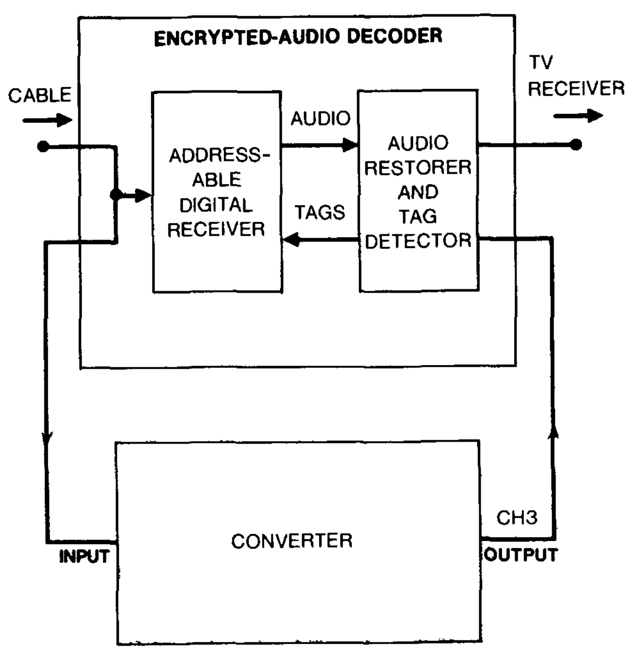

FIG. 2. POST-CONVERTER AUDIO RESTORER

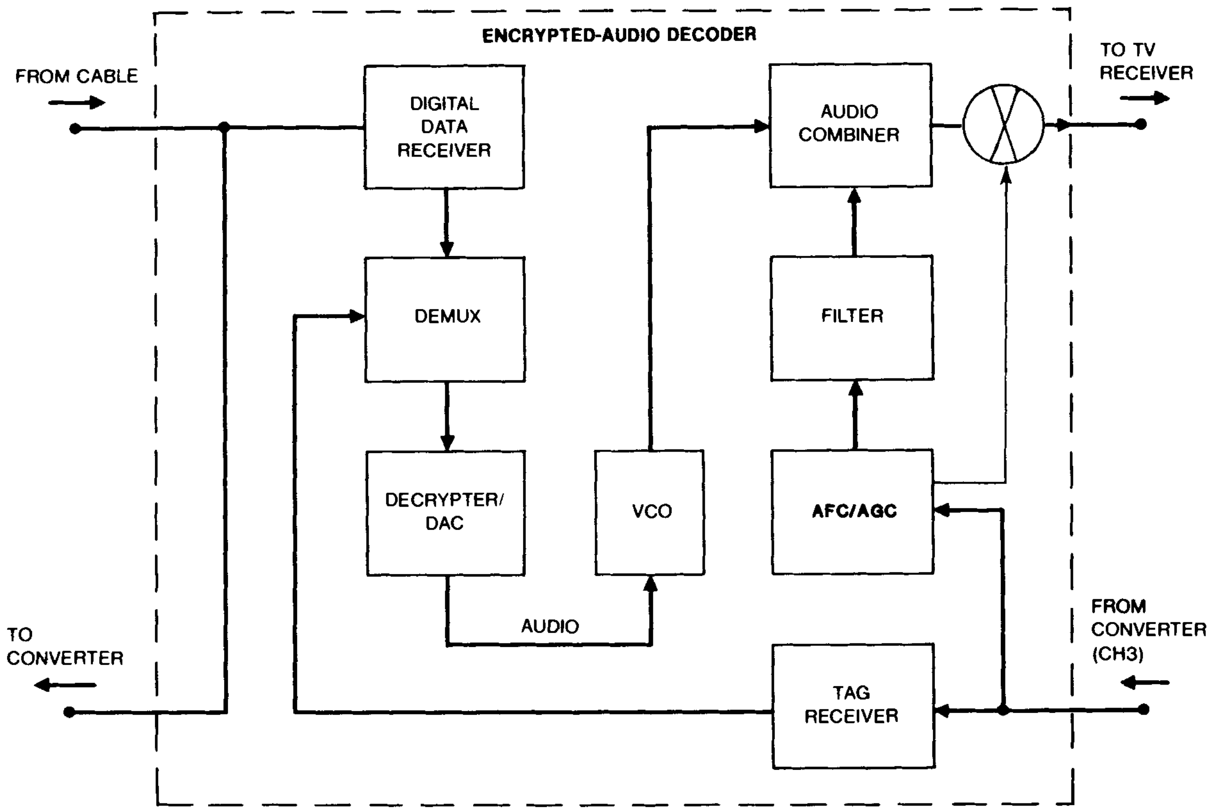

FIG. 3. AUDIO DECRYPTOR/RESTORER

Comparison of the Two Methods

Both proposed methods employ addressable devices, using time-proven tag-matching methodologies. In both cases basic service can be authorized as a single tier, or split into sub-tiers.

The post converter-decoder can be used to control pay services without the use of additional scrambling equipment. The audio denial method, on the other hand, cannot be used to protect all pay services without some additional means of assuming visual privacy. It can be used to enhance the security of analog scrambling methods used to protect pay services.

In both cases, the home terminal device costs about the same -- about half the cost of a converter-decoder. Both techniques are designed around the use of existing converters with the assumption that the converters still have significant remaining useful lives.

The decoder method has limitations in relation to stereo. Inherent in the audio denial method, however, is the ability to deliver a stereo signal.

The greatest contrast between the two techniques is the degree of security. Analog video scrambling techniques such as sine wave or gated sync suppression are relatively unsophisticated. Digital encrypted audio, on the other hand, is now well established as the state-of-the-art in securing cable television signals.

Conclusions

In the cable industry scrambling and addressable techniques have in the past been applied primarily to protect Pay signals. The financial indicators suggest, moreover, that cable is becoming even more dependent upon revenue from basic services. It is time to consider the application of the developments in program security technology to the protection of these "basic service" revenues.

Two converter-compatible methods of securing basic services have been outlined and compared. Regardless of the specific advantages or disadvantages of these particular techniques, it is clear that Pay TV technology can already provide some useful tools to protect cable's primary revenue stream from piracy.

It is timely to re-examine our priorities and determine whether all our efforts to secure signals within cable should be directed at Pay TV and PPV -- or whether perhaps some of this ingenuity is better re-directed to securing "basic!"

IMPROVING FM STEREO ON CABLE

Thomas C. Matty

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A Westinghouse Electric Division

ABSTRACT

FM broadcasting has become one of the fastest growing elements of the broadcast industry. This is a result of the significant technical improvements providing sound quality approaching that of the best original source materials. With the advent of the introduction of stereo to the television broadcast industry, the desire for stereo by the consumers both cable and non-cable has been increasing during the last few years. FM has been available on cable for many years and has been adopted for the delivery of the stereo satellite delivered services. Quality of this product is highly variable depending on the care and skill that is used during the installation and the maintenance that is provided to keep the system up to proper standards.

INTRODUCTION

There are three elements that could be used to improve existing FM service on cable. First of these is to plan for the service, that is, the system operator should address all the technical issues involved in providing the service, purchase the right equipment, and install it according to the manufacturer's recommended procedures. The second element is to correctly set up all the adjustments that are associated with the FM delivery of signals. There are basically two related to this. One is the carrier level and the second is the deviation level. A third adjustment that is required, in some cases, is the troubleshooting of stray noise sources that can impede the proper delivery of FM. Finally, the third element involved is to provide a proper preventive maintenance and troubleshooting technique that will assure correct optimum delivery to the subscriber's home.

PLANNING FOR THE SERVICE

There is a variety of equipment available that is used to deliver both off air and satellite delivered simulcast, as well as the new BTSC off air format in the FM band. Before the installation begins, the wiring practices that are used in the head end should be monitored. It must be remembered that different rules apply to audio wiring than what is used for R.F.

The goal for the delivery of FM should be at least a 60 dB signal to noise ratio in audio at the output of the FM receiver. To achieve this, much care is required in the wiring of the head end to avoid stray pickup of audio sources such as that which may occur from a nearby television set with its horizontal field emissions.

The other issue that may be bothersome to some is hum pickup from various 60 cycle sources that may be near the audio cable. After the installation is complete, a thorough check out of all the audio sources should be performed to verify that a better than 60 dB signal ratio is available for all the sources. This is typically done by connecting the appropriate measuring equipment, either an oscilloscope or an AC volt meter, to the audio input points on the modulator equipment and verifying that when no signal is present, that a noise level is 60 dB below the maximum peak level of signal that is expected to be delivered to that audio input.

FREQUENCY SELECTION

As part of the system planning, it is important to address the FM channel frequency selection. As with television sets, FM receivers emit from the input terminals a small amount of the local oscillator frequency. In the FM receiver this local oscillator will be 10.7 megahertz above the tuned frequency. That is, if the receiver is tuned to 88.1 megahertz, then the local oscillator will be 98.8 megahertz. As with most RF circuitry, this oscillator may not be the purest sine wave and may have many harmonics associated with it. For instance, if the FM receiver is tuned to 88.1, which generates the 98.8 local oscillator, then that second harmonic may be in the 180 megahertz range; the third harmonic may be in the 270 megahertz range. This emission of the local oscillator could result in interference with the video channel. This is not a new problem because a similar situation can and does occur when two TV sets are used within the same household when connected via a splitter. In that case, the video IF difference frequency is the one that should be addressed.

Shown in Table I and Table II are the results of a calculation that indicate for all the normal TV channels which FM frequencies should be avoided for each of the particular channels. It should be noted that not every TV channel has possible interference from the FM receiver. For instance, there is no interference possible for channels two through nine. On channel ten with a video carrier of 193.25, it is possible that a second harmonic of the local oscillator could interfere because if the receiver is tuned to the low end of the band near 88.1 megahertz, this could result in a second harmonic (197.6) of the local oscillator lying in the video band associated with the channel ten carrier.

The table shows the channel number, the corresponding video carrier frequency, the harmonic of the local oscillator that could possibly result in interference, and the resultant unusable FM band associated with that channel. This is not a severe problem, since the protection is only necessary for the six megahertz normal video carrier band. Listing one is for a short basic program that describes the calculation of the interfering frequencies. H is the harmonic of the FM local oscillator and should be tested normally between one and four. F, as shown, is the video carrier frequency.

This problem of local oscillator interference is only important for simulcast operation. That is, for each

STANDARD FREQUENCY PLAN

ch#	video freq	harm	UNUSEABLE FM BAND		
0	109.25	1	97.300	to	103.0500
1	115.25	1	103.300	to	109.0500
10	193.25	2	85.300	to	88.1750
11	199.25	2	88.300	to	91.1750
12	205.25	2	91.300	to	94.1750
13	211.25	2	94.300	to	97.1750
14	121.25	1	109.300	to	115.0500
15	127.25	1	115.300	to	121.0500
23	217.25	2	97.300	to	100.1750
24	223.25	2	100.300	to	103.1750
25	229.25	2	103.300	to	106.1750
26	235.25	2	106.300	to	109.1750
27	241.25	2	109.300	to	112.1750
28	247.25	2	112.300	to	115.1750
29	253.25	2	115.300	to	118.1750
30	259.25	2	118.300	to	121.1750
36	295.25	3	87.300	to	89.2167
37	301.25	3	89.300	to	91.2167
38	307.25	3	91.300	to	93.2167
39	313.25	3	93.300	to	95.2167
40	319.25	3	95.300	to	97.2167
41	325.25	3	97.300	to	99.2167
42	331.25	3	99.300	to	101.2167
43	337.25	3	101.300	to	103.2167
44	343.25	3	103.300	to	105.2167
45	349.25	3	105.300	to	107.2167
46	355.25	3	107.300	to	109.2167
47	361.25	3	109.300	to	111.2167
48	367.25	3	111.300	to	113.2167
49	373.25	3	113.300	to	115.2167
50	379.25	3	115.300	to	117.2167
51	385.25	3	117.300	to	119.2167
52	391.25	3	119.300	to	121.2167
52	391.25	4	86.800	to	88.2375
53	397.25	4	88.300	to	89.7375

TABLE 1

Standard Interference Bands

HRC FREQUENCY PLAN

ch#	video freq	harm	UNUSEABLE FM BAND		
0	108.00	1	96.050	to	101.8000
1	114.00	1	102.050	to	107.6000
11	198.00	2	87.675	to	90.5500
12	204.00	2	90.675	to	93.5500
13	210.00	2	93.675	to	96.5500
14	120.00	1	108.050	to	113.8000
15	126.00	1	114.050	to	119.8000
23	216.00	2	96.675	to	99.5500
24	222.00	2	99.675	to	102.5500
25	228.00	2	102.675	to	105.5500
26	234.00	2	105.675	to	108.5500
27	240.00	2	108.675	to	111.5500
28	246.00	2	111.675	to	114.5500
29	252.00	2	114.675	to	117.5500
30	258.00	2	117.875	to	120.5500
36	294.00	3	86.883	to	88.8000
37	300.00	3	88.883	to	90.8000
38	306.00	3	90.883	to	92.8000
39	312.00	3	92.883	to	94.8000
40	318.00	3	94.883	to	96.8000
41	324.00	3	96.883	to	98.8000
42	330.00	3	98.883	to	100.8000
43	336.00	3	100.883	to	102.8000
44	342.00	3	102.883	to	104.8000
45	348.00	3	104.883	to	106.8000
46	354.00	3	106.883	to	108.8000
47	360.00	3	108.883	to	110.8000
48	366.00	3	110.883	to	112.8000
49	372.00	3	112.883	to	114.8000
50	378.00	3	114.883	to	116.8000
51	384.00	3	116.883	to	118.8000
52	390.00	3	118.883	to	120.8000
52	390.00	4	86.488	to	87.9250
53	396.00	4	87.988	to	89.4250

TABLE 2

HRC Interference Bands

particular video channel there is a band of FM frequencies that cannot be used to deliver that video channel's simulcast audio service.

```
H = Harmonic of FM local oscillator
F = Video carrier frequency

1010 FOR H=1 TO 5
1020 LO=((F-1.25)/H)-10.7
1030 LH=((F+4.5)/H)-10.7
1040 IF LO>87.9 AND LO<120 THEN
     LPRINT USING A$;CN,F,H,LO;" to ";LH
     :GOTO 1050
1045 IF LH>87.9 AND LH<120 THEN
     LPRINT USING A$;CN,F,H,LO;" to ";LH
1050 NEXT
```

LISTING 1
Program to Compute Interference

INGRESS

One other point when selecting FM frequencies is to address the issue of local ingress. Although the leakage into cable systems is small, there may be some situations where the FM broadcast station may be located in such a way that its ingress is amplified by the cable system resulting in an interference from that same frequency that would be used on the cable. This, in effect, is a classical multipath problem because the signal that is broadcast through the air and reaches the cable system along its length interferes or may be out of phase with the signal that is picked up by the off air signal and introduced at the cable head end. If there is a situation in the cable system that allows this to happen, severe distortion results in the audio material delivered to the customer. This problem is easily checked by testing the FM band at the extremities of the cable system when no carriers are generated at the head end. If carriers are found to be present without them being generated at the head end, then those frequencies should not be used. It has been experimentally measured that if a carrier of the same frequency is greater than 40 dB below the proper carrier, that frequency should not be used due to the multipath distortion which results.

ADJUSTMENTS

After the equipment has been properly installed and the signal to noise ratio of all the audio sources has been verified, then the modulators that are used to modulate the various audio material into the respective FM frequencies should be adjusted and verified. The adjustment of carrier levels is one of the easiest to do, since a spectrum analyzer or signal level meter is used. However, if the modulator is provided with a deviation adjustment, this is a very difficult procedure to properly perform. Unlike reading a meter when you are adjusting for an AM process, the FM process generates about the FM carrier a multiplicity of side bands. With the FM process, the only stationary display of information is produced when a single tone is connected to the input of the modulator.

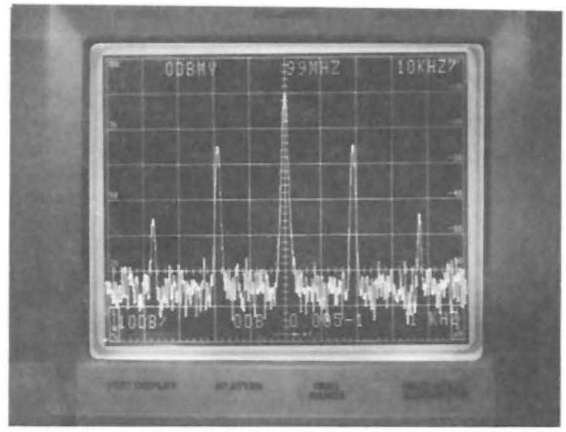

Fig. 1
Unmodulated 99 mhz with stereo pilot

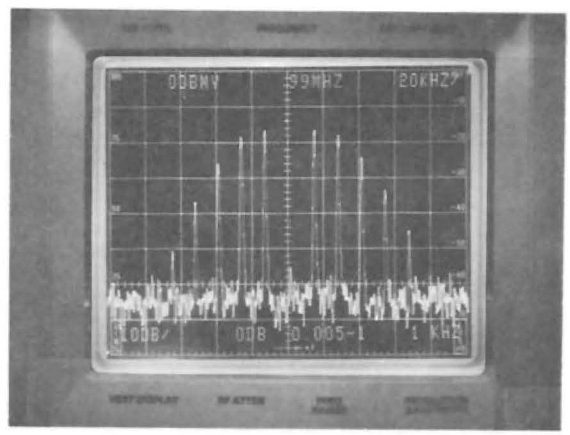

Fig. 2
FM modulation with audio frequency and amplitude adjusted to eliminate FM carrier

Figure I shows the display of a spectrum analyzer for a 99 megahertz carrier without modulation other than the pilot tone. On first glance, this appears to be correct, however, it should be noticed that there does exist a small amount of the (L-R) stereo subcarrier which exceeds the proper limits that are recommended for stereo broadcasting.

Figure II shows the spectral plot with an audio input with the input adjusted to result in the first Bessel null for the carrier. That is, the audio frequency and amplitude have been adjusted so that there is no energy existing at the basic carrier frequency. All the energy is contained within the side bands associated with the FM modulation.

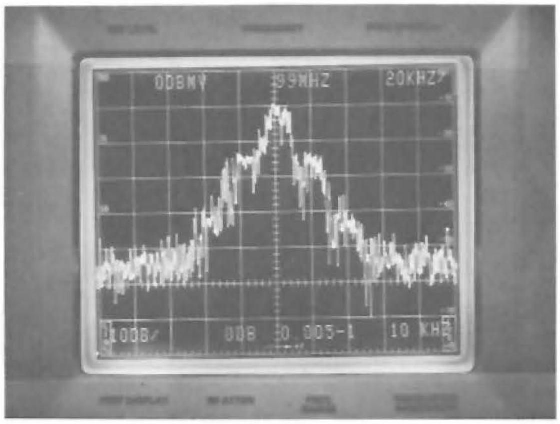

Fig. 3

FM modulated with speech program material

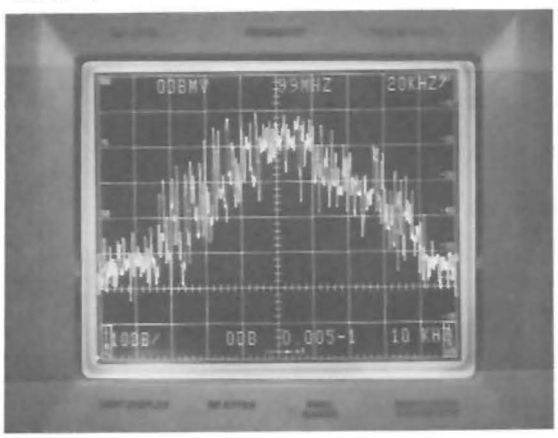

Fig. 4

FM modulated with compact disc music

Figure III is a spectral plot with an FM carrier modulated with some speech material. Notice that the carrier and the pilots are almost hidden but still recognizable at the plateau points along the plot. Figure IV shows a correctly modulated FM carrier with source material from a compact disk music selection. Here you can see that the carrier and the pilots have been totally lost due to the modulation effects.

The point of the above photographs is to show that it is difficult to correctly adjust the FM deviation correctly. Each of the manufacturers provides the correct adjustment procedure, and this should be followed as closely as possible to assure that maximum deviation is being used. Some FM receivers designed for cable and some of the newer FM receivers for off air use are now designed with wide band IF and discriminator processors which allow the processing of significant over deviation. Therefore, if adjusting the deviation level of an modulator, it is not that important if the level is set on the higher side than what you would normally expect. If it is adjusted on the lower side, this results in the loss and audio signal ratio.

OTHER PROBLEMS

Another issue that is being investigated at the present time is the degradation of FM delivery when the FM is distributed via AML links. Theoretically, with FM the signal to noise ratio continues to improve as you keep increasing the carrier level. However, in one recent experiment it was found that the AML link creates an effect which raises the noise floor of the resultant audio baseband signal if the carrier is raised to its full recommended value. It was found experimentally that by adjusting the gain of the buffer amplifier that drives the AML link that there is a minimum noise point which is considered to be less than the optimal noise point from a carrier level viewpoint. This minimum noise point in this one particular case was found to be at FM carrier levels at about -12 dBmv to -14 dBmv.

CONCLUSION

Recent experiments have indicated that FM can provide a high-quality audio service for delivery of FM radio, FM simulcast, and FM delivery of off-air BTSC signals. Tests have indicated that 60 dB noise figures are obtainable if proper care is given to the installation and adjustment. It has also been determined recently that there are elements within the existing head ends that degrade the FM performance to marginally acceptable levels. There are three recommendations that may be useful to improve the delivery of the FM product.

First, is to set the system up correctly, verify the cleanness of the audio signals, verify the correct setup and adjustment of the FM modulators, and verify that the correct deviation and signal levels are provided on the cable.

Second, monitor the operation. Most head ends with the fans and the other noise associated with the operations of head ends are not conducive to correct monitoring of FM signals. If necessary, perform periodic zero modulation noise test. This would be done by removing the modulation to the modulator and connecting an appropriate FM receiver on the cable at some point and measuring the noise level. Establish a log for this noise level on all the channels and monitor the operation periodically. Pay particular attention if you are using FM on AML links. Just simple level adjustments may not be sufficient. It may be necessary to perform a minimum noise adjustment to supply the customers with the best products.

Finally, educate your technicians and engineers on FM so that they understand it and can properly assess the correct operation, as well as they do on their video services.

ACKNOWLEDGEMENT

I would like to thank the many cable systems that helped us. I would also like to thank George Grifith of the Westinghouse Research Labs, and John McDonough, of W&S Systems, for their valuable assistance in preparing some of the technical material for this paper.

LOCAL AREA NETWORKS and CABLE TELEVISION

by

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Transmission of non-entertainment services on CATV facilities has been the theme of numerous "weary prophets" for the last two decades. Although many steps have been taken in this direction, non-entertainment services have not become significant generators of additional cable system revenue. This is not to say that nothing has been done, but simply that the healthy business which was predicted and hoped for has never developed. During this time, however, a whole new segment of communications has evolved within the commercial, industrial and institutional sectors, becoming what we now know as "local area networks", utilizing baseband, broadband and fiber optic transmission media.

We shall briefly examine the development of local area networks and focus upon the kinship of broadband LANs and cable television technology.

EVOLUTION OF THE LAN

Traditional communications such as telephone, telegraph, telex, etc., have been with us for generations, as has the telephone network, which has provided the bulk of communication interconnections. With the advent of the mainframe computer, data volumes began to increase and the business of data communications started its astounding growth. Development of mini- and microcomputers compounded the situation. Computer terminals and peripherals multiplied, not to mention the need for computer-to-computer communication. The computer revolution has been driven by forces from all corners of modern civilization. In industrial, commercial and institutional areas this proliferation required enormous quantities of wire for interconnection and continued changes to keep abreast of the dynamics of the situation. In addition, higher data speeds were needed to efficiently support high density services such as computer graphics.

In short, the data communications, computer and automation industries needed a better way to cope with these dramatic increases, particularly in the areas of concentrated communications such as industrial plants, office buildings, universities, hospitals and the like — hence, the local area network. Designed to carry large volumes of diverse traffic over limited distances, LANs must be compatible with a wide variety of interfaces and data formats and must provide connection to "the outside world". Local area networks are far more sophisticated than the point-to-point and multi-drop circuits traditional in communications of prior years. They allow access to anyone on the network to pass a wide variety of traffic to other points on the network. In effect, all traffic is mixed and each terminal is arranged so that message recipients can sort out their own messages and retrieve them from the mass of other data.

The generalized local area network configurations are STAR, RING, and BUS architectures. A STAR, as the name implies, is configured about a central hub serving terminals with spoke-like connections and is reminiscent of the telephone network. The equivalent of a telephone switch employed in STAR LANs is far more sophisticated than the traditional voice switch. It can handle very high speed data (and may or may not handle voice) and perform extremely rapid switching. Digital PBX's, designed to carry voice and data, are a form of local area network capitalizing on the dual functionality. Some newer digital PBX systems even offer limited video transmission. A STAR network offers dedicated connections to all users, at the expense of somewhat inflexible configuration and a great deal of wire.

Another generalized LAN architecture is called a RING. Here messages are passed serially from terminal to terminal. They are regenerated at each terminal where traffic may also be extracted or added. Users share the network in a time division manner. No master control station is needed since each terminal has the network protocols in its own software. These networks are often implemented with fiber optic technology which lends itself readily to ring operation. One disadvantage of the ring structure lies in the fact that failure of any station on the network will disrupt all traffic which must pass through that station.

A BUS type of architecture is a little more difficult to describe physically. A bus is basically a common transmission path which all stations share on a time division basis similar to the ring. A message from one node need not pass through any other nodes except the one for which it is destined. The network protocols are resident in each terminal unit. This type of distributed architecture boasts high reliability through elimination of common data processing equipment. Failure of a terminal unit affects only traffic which must pass to or from it. Even though broadband networks usually employ a physical tree-and-branch configuration they fall into the BUS category from the data transmission perspective. Broadband networks have achieved widespread popularity due to the proven and straight-forward transmission technology and large bandwidths allowing multiple services, very high capacities and ease in equipment attachment throughout the network. As we all know, broadband networks can readily handle many data paths and configurations plus multiple video channels, and ultimately various types of voice traffic.

There is point of parlance to be noted here. The term "local area network" is used both to describe the entire physical multi-service network, i.e., the broadband local area network in a manufacturing plant, as well as a single group of terminals linked by a specific protocol, several of such groups might be carried on a single physical LAN.

The severest limitation of broadband networks at this time seems to be the lack of equipment to perform the "plain old telephone service". Telephones are almost universally necessary, but require wire other than the coax and hence detract somewhat from the overall attractiveness of the medium. Broadband, however, is being employed in a wide spectrum of LAN service and has been accepted as a standard by major users, such as General Motors, branches of the U.S. Government and many universities and is in use in thousands of locations.

The subject of local area networks cannot be dismissed without some mention of network access methods. Ideally, this type of network should permit random access and provide for all users whether their traffic requirements are large or small. When you consider the range of data rates, interfaces, protocols, etc., this is a big order. The general solution is to care for the interface, data rate and buffering requirements in the terminal unit (often called Bus Interface Unit or Network Interface Unit). Assuming these requirements have been accomplished the next step is to gain access for the traffic to the main data stream. Since the STAR network is basically a collection of point-to-point circuits controlled by a switch, the following comments do not directly apply, however, there are many similarities in the operation of the switch. The RING and BUS architectures operate with a common data stream for all users, so that the protocol that we speak about is basically that set of rules that governs access of a given terminal to the main data stream.

Multiple stations have been very successfully controlled by multi-drop and polling techniques. Polling protocols have been used which are very efficient and dependable. Polling systems, however have the disadvantage of requiring a central controller which then becomes a place of extreme vulnerability since failure of the central controller will disable the entire network. In order to overcome this deficiency the LAN protocols of today have been developed.

A given LAN terminal when it is receiving must simply listen for messages addressed to it and copy them. When the terminal has traffic to send, however, there are several general LAN protocols which may be employed. The first general area includes the contention protocols such as the very popular CSMA/CD (Carrier Sense Multiple Access/Collision Detection). In CSMA/CD a terminal wishing to transmit listens on the common data stream. When it hears no traffic it transmits its data. In order to confirm the integrity of the message it checks the same data after it has traversed the entire system and returned to the receive side of the transmitting terminal. The transmitting terminal then checks the received message and if it is unflawed it assumes that the transmission has successfully reached its destination. (It is well to note that the external protocol of the particular data circuit being served may request acknowledgement in order to fully confirm receipt of the message). If the transmitting terminal fails to receive the identical message back it assumes that the entire message was lost and tries again. Such message loss is often due to collisions with other transmissions as various units contend for the network. In order that collisions do not repeat and propagate, a unit sensing a collision with its transmission backs off for a random period before it tries again. The CSMA/CD protocol has been very successful except that when the network usage is high, more and more collisions develop and limit the throughput and in certain cases can paralyze the network.

In order to improve this situation more sophisticated protocols such as, token passing have evolved. Token passing, as the name implies, generates a unique signal and only that station having that signal in its possession can transmit. This is what is known as a deterministic protocol and can be counted upon for higher throughputs and avoids network paralysis.

It is not the object of this paper to thoroughly discuss LAN protocols; however, it is important to understand that a great deal of work has been done in protocol development and standardization. Perhaps the most concentrated and universally accepted protocol definitions have been developed by the International Standards Organization (ISO Model for Open Systems Interconnection) and IEEE 802 committees. The IEEE committees and their associated LAN standards are as follows:

802.1	Network Management
802.2	Logical Link Control Specifications
802.3	Carrier-Sense Multiple Access with Collision Detection (CSMA/CD)
802.4	Token-Passing Bus Access Method and Physical Layer Specifications
802.5	Token Ring Access Method and Physical Layer Specifications

802.6 Metro Area Networks

802.7 Cable Management Task Force

When all is said and done, local area networks have been developed to meet present day needs and represent a major area of communications. Many of these networks are implemented on broadband. Unfortunately for the cable industry, the LAN market has done an "end run" around us utilizing our technology in areas of highest importance and value in industrial, commercial and institutional environments. We have been left behind.

BROADBAND LAN's and CATV SIMILARITIES

As mentioned before, broadband LANs have been developed solidly upon CATV technology. Cable television hardware and system design is considered to be mature and reliable. There are multiple vendors producing competitive, high-quality hardware allowing the LAN designer firm assurance that he is not dealing with a technology which is "here today and gone tomorrow". LANs are generally designed to video specifications, since video transmission is the basis upon which the transmission hardware has been developed. There are very few components used in present day broadband local area networks which are not taken directly from CATV equipment lists.

By necessity virtually all LANs are two-way. The reason for this is obvious in that most of the communication needs are "request and response" or "command and status" in nature. It therefore follows that there is generally a balance of upstream and downstream traffic. For this reason single cable LANs are usually of the mid-split variety. Mid-split is used in the sense of "equal split", therefore, systems with broader bandwidths generally end up in the "high-split" or "super-split" categories, by CATV terms.

A single cable LAN is simply a mid-split architecture where the cable is routed to all parts of the facility where communications are or will be needed. The system is designed and installed with taps to accommodate the "passings" which in this case might be all offices or every possible work station in a large area, or perhaps every two-hundred square feet, or every column in open manufacturing space, etc. One very important advantage of broadband is that a properly designed system does not have to be disturbed to make moves, additions, or deletions of terminal equipment. The cost of operating downtime to make network extensions usually more than offsets the cost of a comprehensive design and complete installation, often in a very short period of time.

One of the major differences between typical CATV and broadband LANs regards size. A typical LAN for a modest industrial or commercial installation may utilize less than a mile of plant. A 20-mile LAN is a large one and may support 10,000 drops. The layout of an LAN to cover offices or a grid in a manufacturing area often results in relatively close spacing of taps and drops. Eight-way taps are commonly employed. This means that there is less cable loss in a typical run (and a higher percentage of flat loss) and often a lower range in tap values. This gives the feeling that LAN design may be somewhat simpler than CATV design. There are, however, some mitigating circumstances. First, it is common and often necessary to hold tighter tolerance on tap levels than in traditional CATV. In some cases LAN designers use taps with adjustable pads built in to allow trimming to the precise tap level desired. Beyond that it must be remembered than an LAN is a two-way cable network; therefore, the upstream design must match the downstream design. In this regard it is desirable that all modems be preset to the same transmitter output level so that there is one common alignment for all modems allowing new or replacement equipment to be installed without field adjustment. A few "back of the envelope" calculations will show the difficulties encountered in matching slopes and levels, upstream and downstream, to achieve $\pm$ 1.5 dB tap level tolerances simultaneously with a $\pm$1.0 dB spread of transmitter levels arriving at the headend.

Some LAN users have chosen dual trunk systems. A dual trunk configuration might typically employ cable carriage from 40 to 400 MHz on both inbound and outbound cables. A dual cable LAN takes the signals from the inbound cable to the headend and simply combines them with the other inbound trunks and reverses the flow to the outbound cable without frequency translation ("regeneration" or "remodulation" of some signals may be performed at the headend). Notice the difference between this and CATV dual cable where 50 - 450 MHz may go downstream simultaneously on two parallel cables and there may be one or two sub-split upstream paths requiring frequency translation of any upstream (inbound) signals desired on the downstream (outbound) path. Dual cable LAN systems eliminate the spectrum losses caused by diplex filters but normally do not use the range from perhaps 5 - 40 MHz, which in part offsets the first saving.

In single cable usage modems are generally configured to transmit at low frequencies and receive at high frequencies (although this is not universally held). Modem frequency assignments in a dual cable system usually employ transmitter and receiver frequencies within the same general frequency range of a few TV channels. This is a convenience because it allows blocks of contiguous spectrum to be allocated to a certain network or service and does not require frequency translation. It also somewhat simplifies modem design due to the similar transmit and receive frequencies. On the other hand, with connections from each cable going to each modem in the system, there is the potential of excessive local coupling between cables interfering with the desired signals which have been returned from the headend. The requirement here is that modems must have sufficient isolation to limit the maximum possible coupled signal to an insignificant level in terms of data channel interference.

RELIABILITY

Obviously, reliability and availability are key in LAN operation. In considering the cable system itself, redundancy is often employed in a number of ways. In the layout of the physical plant it is well to establish diverse trunk cable routings, thereby limiting physical damage at any one location to a single trunk. In other words, multiple trunks should be dispersed and ideally only come together at the headend. Where redundant cable exists it should be routed separately from the main system. In one design two interleaving systems were used so that any location served was near to both systems. In case of a failure on one system an easy switch-over could be accomplished, restoring circuits quickly.

Power systems should also be designed so that failure of one power supply does not affect both the main and backup systems. Distributed standby power is often used, however, location of all power supplies in the headend is desirable if possible. If standby power is provided for the headend equipment it can also be provided for the entire power system from the same source. Headend-mounted power supplies are protected from physical damage and are also provided a more favorable operating environment.

In broadband LANs great emphasis is placed on system performance. Frequent level checks, rebalancing as required, leakage monitoring and repair (which guards against data channel interference from ingress) and other measures are employed to continually optimize system performance. One of the important tools for system maintenance is broadband status monitoring. There are a number of status monitoring products available to the CATV industry, most of them associated with the trunk amplifiers. Usually, measurements of pilot levels are made and checked against nominal and reports of the system flatness are generated for each amplifier. Other data is collected on individual amplifier parameters such as voltages and internal temperatures. Some status monitoring systems employ upstream switches for location and control of ingress. Status monitoring system reports are usually displayed on a stand-alone computer or terminal.

Local area networks employ very sophisticated data communications products. These network products include many devices and methods for gathering statistics and analyzing data transmission performance under the control of a network manager computer. These "network managers" are very comprehensive from the data transmission point of view, however, they do not include monitoring of the medium, in this case, the broadband cable. A more desirable status monitoring configuration for the broadband medium generates information on the medium performance and provides this to the network management computer thereby rounding out the monitoring and control functions by addition of this critical information.

The Network Technologies Division of AM Cable TV Industries, Inc., has recently announced the TMC-8000 product which includes end-of-line status monitoring so that level measurement units can be placed either in-line or at any drop in the entire system. These units are permanently located and are also capable of generating measurement pilots. With a modest headend controller, pilot generation and measurement may be initiated throughout the system at user-selectable frequencies at 50 kHz increments across the spectrum, both upstream and downstream. Measurements of system signals may also be made with the pilots disabled. In addition, three position switches (0 dB, -6 dB, and OFF) may be located throughout the system for ingress location and control. A unique system of calibration allows very precise level measurements providing the control necessary on these critical networks.

All remote units of the TMC system are organized on a narrow-band, polled, two-way data channel to handle both command and status information. This data channel protocol includes data transmission performance analysis of the command and control messages. Diagnostic information gained from the TMC data stream is useful in identifying the parts of the network which exhibit degredation by analysis of data transmission errors. Certain versions of the TMC operating software contain facilities for input of the topology of the cable network (a system map). This information, when compared against the location of failed units, generates pointers to indicate the most probable locations of cable system component failures.

Output of the TMC system is available in three forms. Stand-alone operation is possible with an IBM PC-XT with proprietary user-friendly software. In a simpler version a stand-alone monitor is provided to access the controller. For use with a network management computer, serial data streams in and out convey all necessary information. The TMC comprises a stand-alone status monitoring system with many features optimized for the broadband LAN arena, and is directly applicable to cable systems as well.

CHALLENGES FOR CABLE OPERATORS

Other industries have capitalized upon the high quality performance of broadband networks and the maturity of the cable products available to generate great utility outside of the traditional CATV market. These are areas in which cable operators could have been involved and reaped benefits for participation. In the main, these opportunities are passing us by, due largely to lack of interest on the cable side. The growth of broadband local area networks is increasing even at this late date. Cable operators often have opportunities within their franchises to serve schools, colleges, universitites, municipal governments, commercial complexes and industrial plants. The cable operator who gets the job of designing, installing and maintaining a network can benefit with substantial revenues.

The lowest level of involvement by the cable operator is probably where he simply supplies service to tie together LAN locations. This is usually a straight-forward job utilizing point-to-point circuits. Hardware is available (modems, etc.,) and careful design and maintenance will yield high-quality, dependable performance. Design, installation and operation of entire networks requires deeper involvement, and usually produces more revenues. The action necessary is to seek out local present or potential LAN users and propose participation in their projects.

There is an area which is just now taking shape, in which we may have many opportunities to participate. "Smart buildings" and the "office-of-the-future" are areas where a heavy dependance will be laid upon communications. Broadband has many advantages which qualify it as the most preferable choice in many cases. You know how to use broadband effectively. You may have to learn a little about data but your first job is to design, install and maintain our own technology. You have tuned CATV technology over the years to provide high-quality TV service. That should qualify you to provide high-quality broadband networks for other services. Now is the time to get "up to speed" in these developing areas and aggressively pursue these opportunities.

MASS DESCRAMBLING FOR HYBRID ADDRESSABLE SYSTEMS

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ABSTRACT

The well-accepted advantages of an off-premises, star-switched distribution system, like MH-II, include security of signal and reduction of equipment theft. These advantages have prompted many cable operators to plan system expansions in a theft-prone environment such as Multiple Dwelling Units (MDUs) by using the star-switched technology. This paper reviews the issues of compatibility for implementing a hybrid addressable system comprised of conventional addressable set-top units and star-switched distribution nodes.

The design of a Mass Descrambling System (MDS) that alleviates the need for a clear trunk option is described. MDUs can be placed at strategic points in the franchise area to provide clear signals to nodes where Local Distribution Units (LDUs) are located. The MDS descrambles up to eight channels and then up-converts them to unused channel slots in the distribution system's frequency spectrum. Because the frequency table in an LDU is software downloadable, the up-conversion process is transparent to subscribers. The hardware design objectives for the MDS are performance transparency, cost effectiveness, and universality of the descrambling approach.

The paper includes a discussion of integration issues involved in implementing headend control and communication functions for two systems in a hybrid environment.

INTRODUCTION

Conventional CATV systems employ tree and branch network topology. The network structure was developed as a cost-effective way of distributing a number of TV channels using the VSB-AM/FDM transmission format. The advent of premium programming created the need to control a subscriber's channel reception capabilities from an MSO's central office. Addressability and scrambling/encryption are used as the means of controlling the availability of multi-tiered premium services to CATV subscribers in the network. The demands for tighter security and the subsequent increase in the complexity of descrambling/deencryption circuitry continue to increase the cost of home terminal units (set-top converters) on the subscriber's premises.

The expensive home terminal unit ($100 to $135) undoubtedly reduces the MSO's losses in the signal theft area. However, it exposes the operator to higher equipment theft losses in a high-churn Multiple Dwelling Unit (MDU) environment, especially in metropolitan areas. This is why in the existing builds in metropolitan areas MSOs have not wired theft-prone MDUs with a conventional set-top addressable system. Providing service to these MDUs represents a major area of expansion and revenue growth potential for MSOs.

Unlike conventional addressable set-top distribution systems, an off-premises star-switched system like TFC's Mini-Hub II achieves signal security by denying a subscriber access to the whole signal spectrum. Rather, the control over delivery of service is obtained by transmitting only one or two selected and system authorized channels to a subscriber from a remotely located Local Distribution Unit (LDU). The addressability/authorization function no longer resides within the subscriber accessible equipment and does not require headend signal processing with the attendant possibility of degradation in signal quality or incompatibility with new advances in video services such as stereo audio. The characteristics of the transmission format on the drop and the removal of expensive hardware from the subscriber's premises minimize in an optimum fashion equipment and signal theft losses. Thus it is of great interest for MSOs to plan their system expansions into the MDU environment using star-switched off-premises technology.

ISSUES AND ALTERNATIVES

A "hybrid" system in which off-premises star-switched technology may be added to an existing tree-branch plant creates some compatibility issues:

Descrambling of Existing Premium Channels

Three possible methods of resolving this issue in such a hybrid system are described below.

a. Clear trunk
b. Per-subscriber descrambler
c. Mass descrambler

The clear trunk option means that a separate trunk from the headend carries all signals, including premium, in clear form for distribution to various nodes where LDUs are located. This may be an attractive solution if MDUs are concentrated in a geographic location in a city. This method does not put a limit on the number of scrambled channels. However, the cost of a separate trunk should be justified versus other methods.

The per-subscriber descrambler option implies that the selected channel on the drop for each subscriber is passed through an on-board or attached descrambler module at the RSM in the LDU. Alternatively, the descrambler can be located in the subscriber's premises. Many MSOs are reluctant to provide an unaddressable descrambler in the subscriber's premises because it can be moved illegally in the franchise. Furthermore, there are many scrambling methods, and manufacturers of converters like to maintain confidentiality of their scrambling/encryption techniques as well as communication protocols. This makes it unfeasible to provide a cost-effective universal descrambler solution.

In a mass descrambling system, a number of scrambled channels are descrambled at a node and then usually up-converted with suitable guard bands to vacant frequency slots in the spectrum of the distribution system downstream from the node. The descrambled channels are not assigned in their original frequency slots ("drop and insert") because it is extremely difficult to adequately filter out the energy of scrambled channels without causing deterioration in the frequency response of adjacent channels.

Control and Communication Protocol

Every addressable system follows a unique communication and control scheme to restrict the access of service to subscribers. In a hybrid addressable system the integration of addressability functions of constituent systems provides several options depending upon how far deep into the system various functions are combined.

Level I. The block diagram of this alternative is shown in Figure 1. In this system the billing computer drives the network control computer (NCC) of the off-premises star-switched system as well as the control computer of the addressable set-top system. The RF modems then generate forward control carriers at two different frequencies (75.5 MHz in the MH-II case) to communicate with respective addressable control modules at nodes (LDUs in MH-II) or in subscriber home terminal units (in the conventional portion). This option does not require any hardware, software and/or firmware changes in either system, except, of course, for those changes

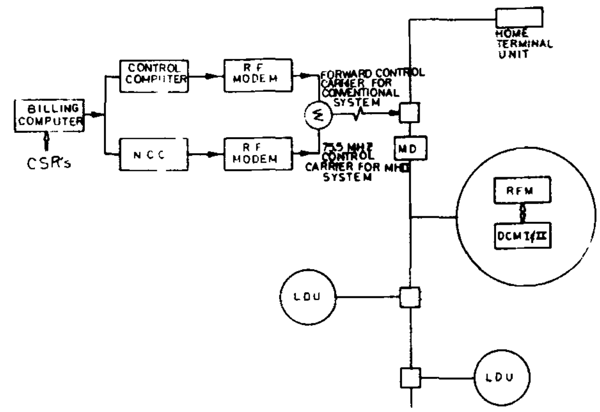

FIGURE 1. HEADEND CONTROL SYSTEM USING SEPARATE COMPUTERS FOR TWO SYSTEMS

necessary to ensure compatibility with the billing system interface and protocol.

Level II. The integration process is carried out a step further as shown in Figure 2. There is only one computer in the system in which the database and screens are integrated. However, control and communication programs as well as RF modem functions for the constituent systems are separate. Thus no hardware or firmware changes in either system's subscriber or off-premises equipment is required.

Level III. At this level, the communication and control protocols are integrated. Firmware changes now may be required in both systems to handle the unified protocol. If the RF modem function is also integrated, hardware changes may be required to achieve compatibility in modulation method and frequency.

The system described in this paper employs integration at Level I for its simplicity and speed advantages.

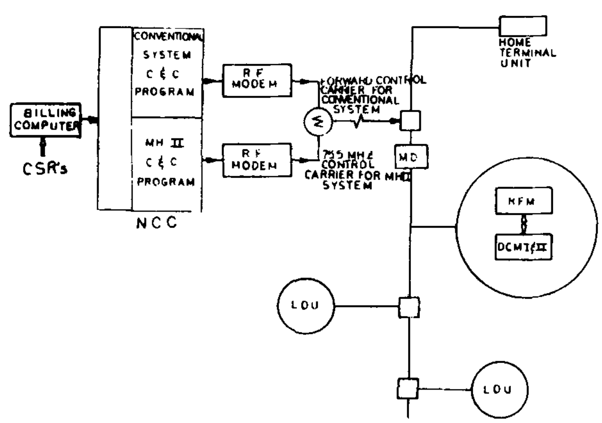

FIGURE 2. HEADEND CONTROL SYSTEM WITH A COMMON CONTROL COMPUTER

MDS BLOCK DIAGRAM AND PERFORMANCE SPECIFICATIONS

The block and level diagram of the aforementioned Mass Descrambling System (MDS) is shown in Figure 3. As can be seen, the 50 to 450 MHz feeder input is looped through with up to 20 dB of gain for system extension. Each channel to be descrambled passes through a separate chain of down conversion, fixed channel descrambling, and final up conversion. After combination, the block of up to eight channels is amplified with sufficient tilt to allow for 23 dB of cable loss at 550 MHz before levels fall below the 10 dBmV minimum required at the LDUs. There is a requirement for a 6 MHz guard band between channels to guarantee that adjacent channel spurious feedthrough falls below W-curve limits. The downstream distribution system and LDUs now have to be 550 MHz compatible.

The MDS unit uses standard MH-II hardware for the enclosure, AC distribution, FM band control carrier module, power supplies, and backplane/signal distribution passives. The decoders or descramblers are provided by the MSO with possible modification to reduce unnecessary power dissipation and eliminate the channel change function. New modules, packaged in existing castings, were developed and are discussed below.

Input RF Amplifier Module (IRFM). This is a 25 dB gain, 50 to 450 MHz line extender quality amplifier with plug-in capability for signal conditioning. To coexist with the available 15.5V MH-II DC supply, a custom hybrid was developed. The low pass filter following this module serves to remove distortion products above the highest channel that have built up in the system.

Channel Selection Module (CSM). This module tunes to one channel in the 50 to 450 MHz band and outputs it on a low band VHF channel dictated by local off air conditions. It is a modification of the existing MH-II subscriber module to accommodate DIP switch fixed channel programming in the field in 62.5 kHz steps. The standard MH-II 18 dB conversion gain SAW filter/SAW resonator based CATV tuner is used.

Variable Attenuator Auxiliary Function Module (VAAFM). This small add-on unit provides 20 dB of gain adjustment and allows the summing of a control carrier in the FM band with the down-converted channel.

Automatic Gain Control Auxiliary Function Module (AGC/AFM). This module is required for RF descramblers where output tracks input on a dB-for-dB basis. By stabilizing the signal level to the upconverter, the system CNR contribution can be maintained with drift of the descrambled channel level. Power is obtained from the upconverter module RF connector.

Upconverter Module (UCM). This module accepts the descrambled low band VHF channel and translates it to a vacant slot in the feeder spectrum usually above the existing carriers because of guard band requirements. The same fixed frequency selection technique as used in the CSM is employed. The critical element that had to be developed was a "reverse tuner" also using SAW technology that has adjustable gain for providing tilt in the final combined system output. This unique module is described in further detail in the next section.

Output RF Amplifier Module (ORFM). This unit provides 29 dB of amplification for the combined translated descrambled channels to provide sufficient level for summation with the carriers in the 50 to 450 MHz band.

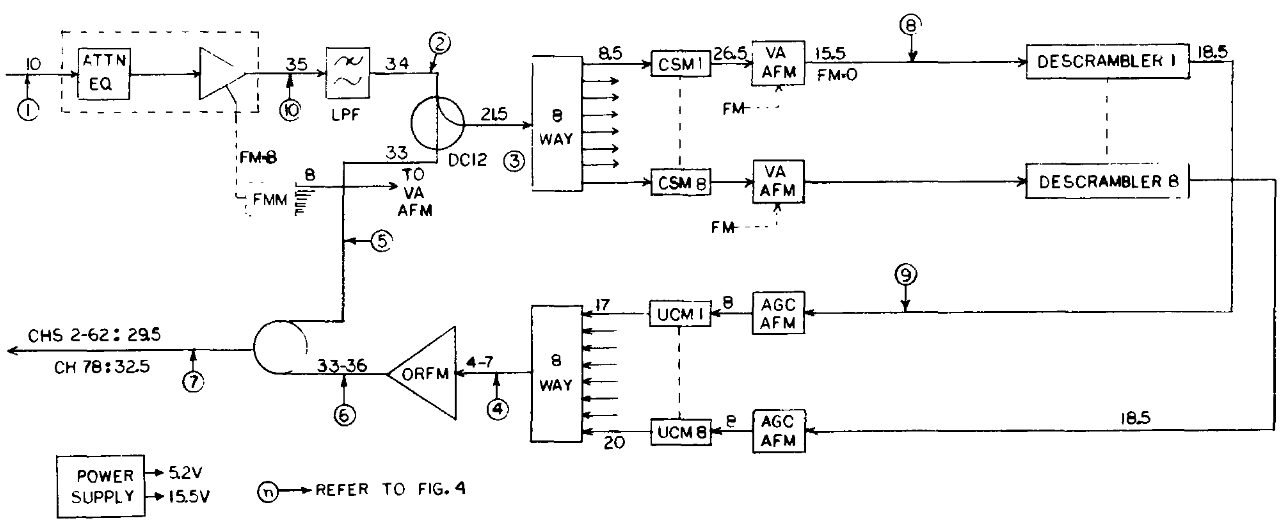

FIGURE 3. BLOCK AND LEVEL DIAGRAM OF MDS

The design goal is to make the MDS as transparent as possible in the critical areas of added noise, distortion, frequency drift, and gain fluctuations. The overall system specifications are listed below.

Return Loss (75 ohms)	
Input (50 to 450 MHz)	15 dB, minimum
Output (50 to 550 MHz)	15 dB, minimum
Input Level (nominal at install)	10 dBmV lowest carrier level
Input Level Drift Range	±5 dB
Signal Conditioning Range	Plug-in pads are available in 3 dB steps. 9 dB of positive true tilt and 15 dB of negative true tilt can be accommodated with plug-in fixed equalizers. These numbers correspond to 13 and 22 dB of cable, respectively.
Noise Figure (10 dBmV input)	18 dB, maximum (CNR contribution = 51 dB)
Insertion Gain	20 dB ±1 dB, 50 to 450 MHz, with 3 dB of tilt from 460 to 550 MHz
Distortion (+15 dBmV flat input)	
Cross mod	-63 dB
Second order	62 dB
CTB and third order	62 dB
Frequency Error and Drift	±50 kHz plus descrambler drift
Bandpass with respect to fpix	
fpix - .75 MHz	-4.5 dB maximum
fpix + 4.5 MHz	-3 dB maximum
Operating Temperature	0 to 50°C

Although the noise figure of the IRFM is 9 dB, maximum, which would lead to a CNR contribution of 60 dB at +10 dBmV input, the spec is 51 dB as this is the CNR contribution of the system for the descrambled channels.

The noise figure for a single channel to be descrambled can be derived by following its path through the loop of Figure 3. Using the data in Table 1 for an RF descrambler scenario, the cascaded noise figure equation yields 17.4 dB with the major contributor being the CSM noise figure/distribution loss term. Different decoder/descramblers would require readjustment of the AGC/AFM and UCM settings. The data in Table 1 for a baseband decoder yield a system noise figure of 17.5 dB. In this case the AGC/AFM module would not be used.

	RF DESCRAMBLING		BB DECODING	
Module	Noise Fig. (dB)	Gain (dB)	Noise Fig. (dB)	Gain (dB)
IRFM	9	25	9	25
LPF/DC12/ 8-Way	26.5	-26.5	26.5	-26.5
CSM	12.5	18	12.5	18
VAAFM	11	-11	11	-11
Descrambler (CH3)	12	3	12	- 8.5
AGC/AFM	10.5	-10.5	---	---
UCM	8	12	8	13
8-Way	13	-13	13	-13
ORFM	6	29	6	29
2-Way	3.5	- 3.5	3.5	- 3.5

TABLE 1. MDS STAGE NOISE FIGURE AND GAIN

The physical layout of the units within a 32 subscriber MHII enclosure is shown in Figure 4 for the case where the descrambler is a small stand alone unit with stable output. The upper two racks hold the common amplifiers, the 8 pairs of converter modules, and the required power supplies. The descrambler shelf assemblies contain AC power strips and metal partitioning shields for isolation between descramblers which may contain local oscillators and, therefore, be susceptible to ingress. The bottoms of these assemblies are slotted to allow proper air flow within the enclosure for cooling.

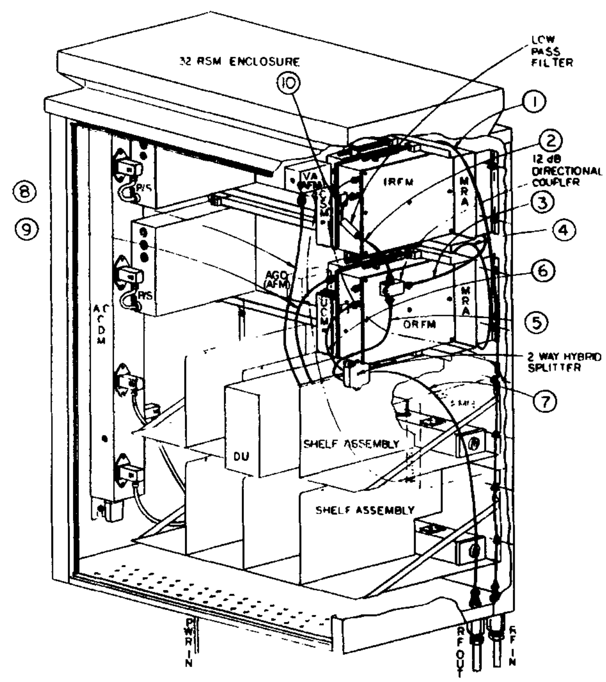

FIGURE 4. PHYSICAL CONSTRUCTION OF MDS

If the MSO chooses to use a full size set-top converter to perform the descrambling function, then a companion 16-unit MH-II enclosure must be used to hold four set-tops. Bulkhead F connectors passing through knockouts in the bottom of the enclosures are then used for the two interconnecting cables required per descrambler. The optional FMM and AGC/AFM modules required for some systems are located as shown.

UP CONVERTER MODULE (UCM)

The UCM design objective requires performance transparency (approaching that of a headend heterodyne processor) as well as low cost, which was achieved by utilizing the packaging techniques of the MH-II hardware. The UCM contains two separate subassemblies; a tuner, and a controller PCB requiring a total of 3-1/2 watts. The block diagram is shown in Figure 5. The module is capable of frequency shifting a low band VHF channel to any slot in the 300 to 550 MHz range with negligible degradation of the channel quality. The reverse tuner, like the conventional version, uses a double heterodyne technique for image rejection and elimination of in-band local oscillator (LO) spurs. The order of the fixed and variable LOs is simply reversed. The second LO is a varactor tuned type controlled by an onboard Phase Lock Loop (PLL), which uses a dual modulus Prescaler to produce a stable broadband selection capability.

The PLL circuit uses a 512 divider to produce a 7812.5 Hz phase comparison frequency from the 4 MHz crystal oscillator output. Because this frequency is half the horizontal line rate, it minimizes video degradation from residual phase modulation. The PLL uses a fixed ÷8 prescaler at the VCO input, which then feeds the dual modulus counter. The combination produces a resultant frequency selection resolution of 62.5 kHz.

The first local oscillator is selected to be 612.75 MHz above the fixed input fpix and employs a frequency stable resonator using a SAW device. There is a SAW bandpass filter at the

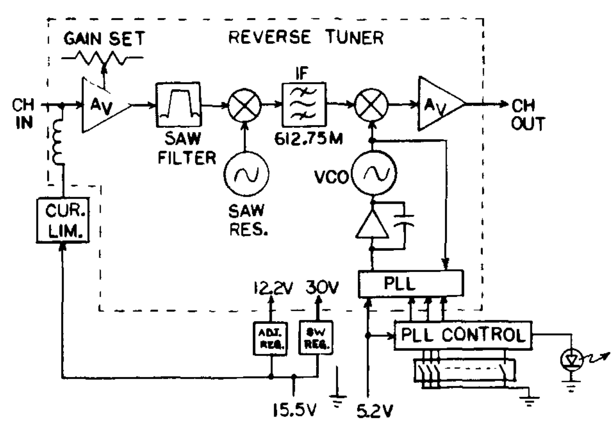

FIGURE 5. UCM BLOCK DIAGRAM

input for adjacent channel rejection. For final setting of conversion gain, the input amplifier has more than 10 dB of externally accessible adjustment range.

The reverse tuner, having only a single channel at the input, has been optimized for noise performance. The only output spur of significance in the present design results from residual first LO signal mixing with the second LO and producing a spur at fpix frequency below the output channel. This beat is maintained at greater than 65 dB below the minimum anticipated output level.

The primary distortion component of the tuner is the inband 920 kHz video beat resulting from the $f_{audio} - f_{chroma} + f_{picture}$ frequency components. This is held to 60 dB below picture carrier level. Finally, the broadband noise output must be limited such that seven other UCM outputs can be combined without appreciably degrading the noise performance of the channel.

The remaining assembly in the UCM provides the reverse tuner with the PLL commands necessary to tune to the selected output channel. The channel is programmed via a series of DIP switches for use by the MSO at the time of installation. These switches are not usually altered after installation.

The operator looks up the channel selection code and selects the DIP switches accordingly. When the UCM is powered on, the data, clock, and load commands are periodically fed to the reverse tuner PLL and a front panel indicator is lit to indicate this activity.

The reverse tuner, having a varactor-tuned second LO, requires a clean 30 volts at low current. This is provided by a flyback switching supply using a UJT relaxation oscillator. The RF circuitry uses the bulk of the power which must be tightly regulated for the tuner's transparency requirement. A three terminal adjustable regulator meets this requirement well. The remaining 5V bus is simply filtered for high frequency rejection since the PLL and control circuitry already have good noise immunity.

HYBRID SYSTEM DESIGN GUIDELINES

From the transmission performance point-of-view, a mass descrambler appears to the system as a line extender with gain of about 22 dB. The cost of descrambling a channel is around $200 to $250 in such a unit. Assuming that a system has eight scrambled channels, the mass descrambler unit may cost from $1.6K to $2K. Consequently, it is desirable that mass descrambler units are strategically located to feed clear signals to a number of LDUs to minimize the descrambling cost/subscriber. The input signal requirement of a MHII system is 10 dBmV for a 32-unit LDU. A typical system layout in a high density metropolitan environment is shown in Figure 6.

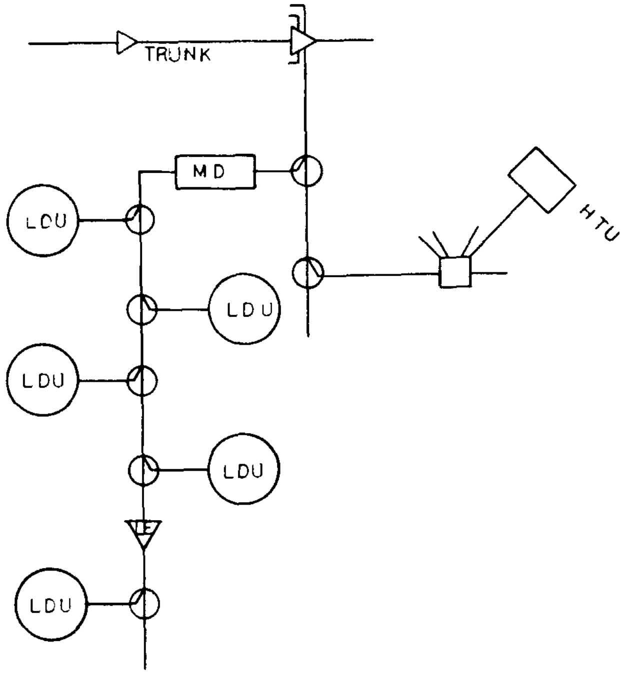

FIGURE 6 TYPICAL MDS DISTRIBUTION SYSTEM LAYOUT

The 22 dB loss budget may allow 3 to 10 LDUs (96 to 320 subscribers) to be supplied from the output of a mass descrambler depending upon the losses in the feeder cable and directional couplers. Of course, a line extender can be added to extend the range of the system. The operating output levels of the line extender should be suitably derated to meet the worst case performance objectives of the franchise.

CONCLUSION

A hybrid CATV distribution system using addressable set-top converters for single family homes and an off-premises, star-switched system for MDUs offers a very attractive solution to MSOs for secure delivery of premium services in metropolitan areas. Although the hybrid architectural concept does not provide the total optimization of a backbone trunk/feeder plant, it may be the only rational choice when offering service to MDUs in the theft-prone MDU marketplace in existing builds.

Undoubtedly, compatibility issues are raised in the areas of headend control and techniques for dealing with the scrambling required by the latter system for security purposes. These issues are resolved in a cost-effective and practical manner by the integration of control and communications functions under the billing system and by mass descrambling at key locations in the franchise area.

MTS STEREO CONSIDERATIONS
"AN OPPORTUNITY OR A CRISIS"

GEORGE R. J.GREEN

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ABSTRACT

This paper considers the current status of the MTS system with regard to alternative delivery systems and reviews some of the current MTS decoder designs. It considers interface requirements, performance characteristics and compatibility with current in-home terminals. New methods in baseband processing are examined to illustrate their full compatibility with the MTS system.

INTRODUCTION

The endorsement of the Zenith / DBX Multichannel Television Sound (MTS) system by the Electronics Industries Association (EIA) has led to an almost universal standard for broadcast TV stereo. This has provided the broadcasters with the opportunity to promote their program software in a new dimension while still maintaining compatibility with the existing monaural transmission and reception equipment. The Cable Industry has been faced with incompatibility issues in both the transmission and reception of the MTS signal. Alternative methods of delivering stereo services to subscribers are currently being reviewed by the Cable Industry. The consumer demand for enhanced audio services is increasing as MTS programs and products are promoted.

The MTS format is, as it turns out, providing a better than anticipated performance and is encouraging an overall improvement in the quality of the received audio for television. In addition, the incompatibility issues initially raised by the Cable Industry are being overcome. The MTS signal format may by default become a defacto standard for all cable programming. Why? Because it is there, it is endorsed by the EIA and it is being heavily promoted at no cost to the Cable Industry by broadcasters and by television and VCR manufacturers. The quality of the MTS signal may not be as good as that of CD players and other premium quality stereo delivery systems. However, it is good enough for consumers who are interested in both the visual and aural presence of a program.

As an industry in a free market place, we have to continually adapt to market trends and deliver new services as the market and consumer demand warrants it. The motivating forces in favor of the MTS system are its compatibility with the existing monaural audio system, the fact that it is endorsed by the EIA and that MTS products are readily available from multiple sources. The questions raised by the Cable Industry of incompatibility and cost crisis are giving way to the fact that the MTS system can be made compatible and that opportunities may exist for enhanced audio services. In any case, the Cable Industry may need to become compatible with MTS in order to remain competitive with alternative program sources. There is of course, the obvious need to meet the growing demands of subscribers who have purchased a new MTS stereo television or VCR.

PRODUCT CONFIGURATIONS

A range of MTS products are currently available to meet the projected demand from consumers. These MTS products can be integrated systems such as stereo televisions and VCR's or component type add-on stereo decoders which can either be owned or leased by the consumer to receive enhanced stereo services.

Our prime concern in this paper is to focus on the component type of stereo decoders. How do they functionally operate? What interface standards should be considered? What are the performance characteristics of these devices? How do they interface with current in-home terminals?

The interface point of any component type of stereo decoder should preferably track the video source to which it is being tuned. To meet this obvious need, in a baseband system the stereo interface can be taken from either the IF, the 4.5 MHz intercarrier audio or the multiplexed baseband audio. In RF type systems the interface has to be at the converter output at either channel 2, 3 or 4. In a baseband converter the channel 2, 3 or 4 RF output can be used, but only if the device is designed to provide sufficient audio bandwidth together with good linearity in the audio and video detectors.In the remodulator the incidental phase modulation should be minimized and the audio deviation has to be accurately maintained for optimum stereo separation. As with all choices, there are compromises and trade-offs in performance and costs depending on the interface point chosen.The layouts illustrated in figures 1 through 3 show typical product configurations for stereo decoders. Note that in all of these configurations the output levels are typically low power levels and are meant to drive either an audio amplifier system or powered loudspeakers.

In figure 1 a multiplexed baseband MTS decoder interface is illustrated. This configuration is common to television set manufacturers and could be used with baseband converters. This concept is probably the lowest cost unit but the stereo separation is very sensitive to the signal level input and must be matched accurately. A remote volume dc control from the television or the converter can also be implemented with this configuration to provide variable left and right outputs. The amount of intercarrier buzz in this system will be determined by the quality of the device feeding it. It is unlikely that this configuration will have much application in cable television. However, it is one of the interface options being considered by the NCTA interface standards committee.

In Figure 2 an MTS decoder with a 4.5 MHz intercarrier interface is illustrated. This system could be used with either a television or a baseband converter and can also provide a remote volume control via the television or converter.This system interface is not susceptible to input signal level variations. The amount of intercarrier buzz in this system also will be determined by the quality of the device feeding it. This system configuration could see considerable application in cable television because of the significant numbers of baseband converters currently in use.

In figure 3 an RF MTS decoder is shown with a channel 2,3 or 4 RF input interface. This configuration is similar to figure 2 but is specifically for converter applications. This too can be designed to provide a remote volume control via the converter as in the previous systems. This stereo decoder has the advantage that it can be designed as a quasi split sound detecter with filtering favoring the audio bandpass.This can reduce the intercarrier buzz and improve the signal to noise by 5dB. This stereo decoder is likely to be the most common application in cable television because of the large base of RF converters. It should be noted that with this configuration any or all of the above input interfaces could be added to this type of decoder. Note also that an MTS stereo decoder with an IF interface would have similar performance characteristics as that of figure 3.

BASEBAND CONVERTER CONSIDERATIONS

Recent developments in baseband converter technology have shown that with proper design and alignment it is possible to demodulate and remodulate the audio signal and still be transparent to an MTS signal. This is possible by using a very linear audio detector and by increasing the audio bandwidth to pass the complete multiplexed stereo signal. The intercarrier buzz is minimized by proper IF alignment and by improving the linearity in the video detector.In the remodulator the audio deviation has to be accurately maintained for optimum stereo separation and the incidental phase modulation has to be minimized. The advantage of doing this is that you can still maintain the volume control and mute function. However,any change in the volume control will significantly affect the stereo separation.

The sensitivity of the stereo separation to volume control was examined using the configuration illustrated in figure 4. This test set-up used current production equipment to determine the effects of stereo separation over a frequency range from 0 Hz to 12.5 KHz. In figure 5 a comparison of the stereo separation of the system versus the system including a Z-TAC II baseband converter is illustrated. In this case, it can be seen that little degradation in separation has taken place and certainly none that could be subjectively observed by a consumer listening to a stereo television.

The effects on separation with changing volume control in a baseband converter are further illustrated in figure 6. Here it can be seen that because of the non-linear characteristics of the MTS encoding, the stereo separation significantly degrades as the volume (deviation of L+R) is reduced in the converter. However, by allowing the audio to overdeviate the carrier, it is possible to maintain a more acceptable degree of separation for a limited amount of volume control. Figure 7 illustrates the effect on stereo separation when the carrier is overdeviated to 30KHz and then correspondingly reduced by 1.5 dB and 3 dB. Comparison of figures 6&7 show that by doing this the separation is improved by 5 dB when the volume is reduced by 3 dB. If such an approach is used to provide a limited volume control, then it is necessary to provide the consumer with some means of control to accurately return to the correct deviation setting for optimum stereo separation.

ALTERNATIVE DELIVERY SYSTEMS

Alternative methods of stereo delivery are being promoted in the Cable Industry. The majority of these are either out of band analog type systems in the FM spectrum or some form of digital audio systems. They may have the potential to offer a higher quality signal to the consumer. However, because there is no predominant standard and no clear market is defined for such an enhanced service, it is uncertain as to how these systems will develop. These systems are further negated because of the potentially higher costs and the question of who will assume those costs. As engineering purists we need to be realistic and not lose sight of the basic business economics. The MTS system is likely to be the lowest cost option for providing an enhanced TV audio service since most of the terminal costs will be assumed by the consumer who has an incentive to listen to the TV broadcast channels in stereo.

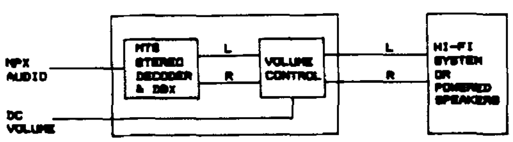


FIGURE 1:MULTIPLEXED MTS DECODER

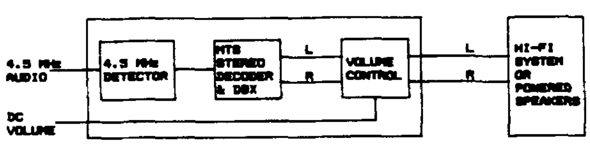


FIGURE 2: 4.5 MHz MTS DECODER

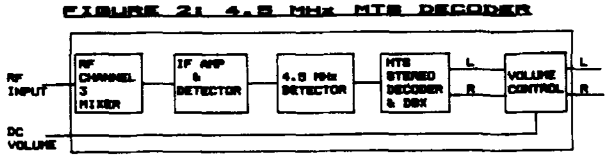


FIGURE 3: CHANNEL 3 RF MTS DECODER

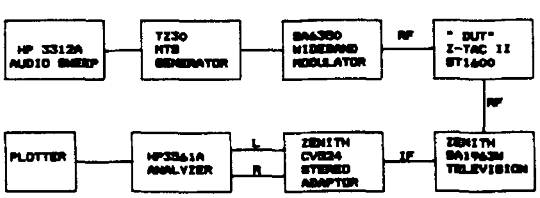
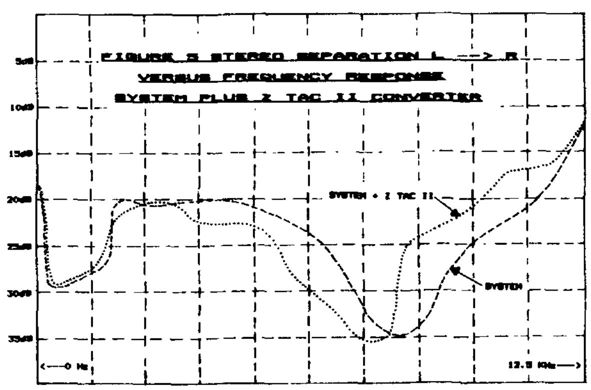


FIGURE 4: STEREO TEST CONFIGURATION

CONCLUSION

The previous sections have shown that a variety of MTS stereo decoders are available with differing interfaces, performance characteristics and costs. It is likely that these MTS stereo decoders will provide a short term solution for cable subscribers until such times as stereo television receivers significantly populate the market place. These products can help the cable operator provide enhanced audio services and remain competitive with alternative media programming. If the MTS system becomes a defacto standard for the Cable Industry, then consideration should be given as to whether it is compatible with the scrambling system being used. Analysis of current parameters would show that in reality <u>monophonic</u> television receivers are <u>typically</u> in the range of 52dB for signal to noise ratio and provide about 6KHz of bandwidth. The signal to noise ratio of FM on cable is <u>typically</u> 55dB and stereo separation on tape recorders and record systems is <u>typically</u> 20dB to 25dB. The MTS system and its circuit development is in its infancy and as the circuit technology advances, the MTS system will probably meet or exceed limits of 64dB signal to noise ratio and provide better than 25dB of separation with 15KHz of bandwidth. In perspective then, the MTS system has the potential to provide an acceptable level of service to the majority of consumers.

FIGURE 5 STEREO SEPARATION L --> R VERSUS FREQUENCY RESPONSE SYSTEM PLUS Z TAC II CONVERTER



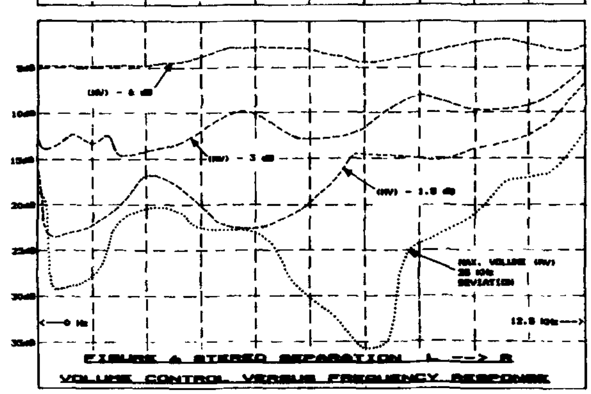
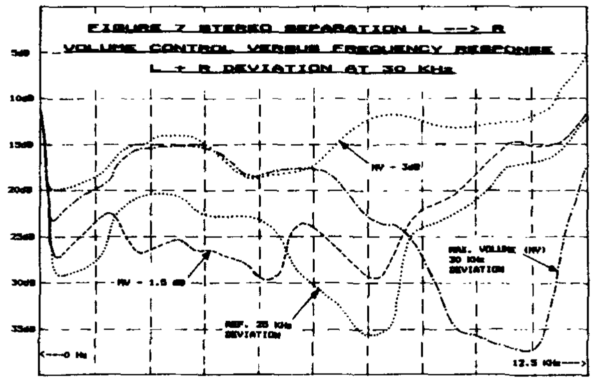


FIGURE 6 STEREO SEPARATION L --> R VOLUME CONTROL VERSUS FREQUENCY RESPONSE



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ACKNOWLEDGEMENTS

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OFF PREMISES SWITCHING:ALTERNATIVES IN CATV CONTROL SYSTEMS

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ABSTRACT

At present, the delivery of pay television signals has primarily involved scrambling of protected signals. This method has several inherent problems, particularly in the area of program and equipment security.

The initial obvious solution was to employ off premises control systems. These system designs are primarily based on off premises converters, which have proven to be less than the ideal answer. It appears that either off premises addressable tap systems, or hybrid tap/scramble systems may prove more effective in this application. This paper examines the functional, application, and cost aspects of various system control technologies currently available.

FUNCTIONAL DEFINITION OF CONTROL SYSTEMS

The ongoing discussions on the relative merits of off premises control have suffered from a lack of functional definition. This lack of definition, and in particular, excursions into non-traditional areas of operation, has generally led to system over-complexity.

The functional requirement can be described as follows, under several categories:

CATV Control	:Program Access
	Normal Pay Control
	PPV Control
Secondary Service	:Interactive Services
	Telephony
	Text Services
Convenience Services	:Channel Selection

These functional requirements can differ in motivation, for example: channel selection is a requirement in British Systems where tuners are not incorporated in TV Receivers, while in North America, channel selection is a byproduct of the control technology employed.

Most attempts at systems to perform these functions are based on the obvious solution of remotely located converter, or converter-descramblers. While this method appears, at first, to perform the majority of desired functions, the operational reality is somewhat less than perfect. This system concept has, however, been attempted by various manufacturers in North America, and has also appeared in Germany as the NIXDORF/FUBA F.A.T.S. system as well as the various versions of British Telecom Switched Star Systems. (CABLETIME, DELTAKABEL ETC.)

As attempts to implement these systems progress, several major constraints become apparent. Of particular note are the following items:

1) The switched star, or off premises converter system,is extremely capital intensive.
2) The requirement for operator equipment in the customer home.
3) The inability to serve multiple receivers without duplicating the amount of dedicated hardware.
4) Incompatibility with cable ready TV's and VCR's.
5) Physical mass of the system.
6) Overall system electronic complexity.

The primary cause may be that the switched star or off premises converter does its job too well, and, in fact, undertakes functions which could be considered as beyond the domain of the CATV operator.

Perhaps we should disgress slightly and examine the proposed functional requirements in the context of a CATV operator.

Basic Service Control	:Primary system requirement
Pay Television Control	:Primary Revenue Generation
Pay Per View	:Primary Future Potential

These are the obvious primary requirements of an off premises system. Many systems also have designed-in capability for secondary services. The following are the most commonly discussed optional capabilities:

Interactive Functions: These are best defined as two way transactional services,such as tele banking, tele shopping, polling, etc. Up to now experiments with this type of service have been just that: experiments. We have seen that, to date, these concepts have been technology driven as opposed to market driven (i.e. how can we sell what we do? as opposed to "how can we do what they want to buy?"). This technologically driven approach to product has invariably led to failure, because it is impossible to sell a technological means to which there is no market driven end. CATV customers are NOT DEMANDING tele-banking, tele-shopping and similar services, nor could they be readily convinced of their need for such services.

Text Services: These services have had success in several very limited applications. In particular, hearing impaired captioning has proven viable, as has text delivery on a narrowcasting basis. Text service have been successful in remote areas, such as Western Australia, where it is normally the first print information to be delivered to the customers. The supply of text services as a revenue generating vehicle on a broadcast scale has yet to be proven viable.

Telephony: The delivery of telephone communcations via the CATV network has been considered primarily by European Government Telephone Agencies. If we observe the operation of a traditional North American telephone system, especially in light of de-regulation and diversification, we can observe one obvious effect : The local telephone network is not necessarily revenue self-sustaining. Traditionally, the telephone network has been self-subsidizing via long haul revenue generation. To isolate the local telephone net, especially in the context of a CATV system which is by nature a localized system, does not hold significant potential as a revenue generating vehicle. In fact, the application of a CATV system to telephony has a somewhat reversing technological effect, in that we must build a telephone network carrying TV as opposed to a TV network carrying telephone service.

Channel Selection: Most television receivers in Europe and the U.K. do not incorporate a multichannel tuner. All North American television receivers have at least a twelve channel tuner, and most medium and high priced receivers have full tuning capacity. The European telecoms, particularly British telecom, have taken the task of channel selection to be the responsibility of the CATV system as a marketing advantage position.

In North American Systems, the function of channel selection has been provided as a by-product of the technology of remote converters, along with the inherent weaknesses of having only one channel at a time enter the customer's home. The overriding question remains : is it the responsibility of the CATV operator to provide channel selection, or is the operator's primary responsibility limited to delivery of the signals?

In order to clarify this situation, the CATV operator must approach the problem from the viewpoint of "what must a CATV control system do?" as opposed to "what can be done with a CATV control system?". The critical requirements of a CATV control system are:

1. Secure access to basic and premium programming.
2. Reduce the cost of ongoing field service caused by basic connections, disconnects, pay churn, etc.
3. Provide a vehicle to support the sale of impulse programming, and demand services.
4. Allow full use of customer owned video and audio equipment at a reasonable capital cost!

The foregoing items require a careful analysis of the proposed control system, realizing that optimum design may result from a mix of technologies as opposed to a single all encompassing technique. It is much more critical that the system be upgradable than to try to allow for all possibilities at the outset.

AVAILABLE OPTIONS IN CATV CONTROL NETWORKS

When we approach the three primary functions of CATV Control, these being; Basic service access, Pay television security, and Potential Pay Per View, we have various technologies at our disposal.

It is primarily the"Pay Per View"requirement which complicates these options. When we were dealing with only Basic and Pay television, it was possible to employ totally static or passive methods; i.e. drop control and traps, or similar devices. Pay Per View, by virtue of timing requirements,requires active or dynamic control systems.

Thus, in today's system we have the following available options:

- addressable scrambling
- off premises converters
- addressable taps
- a combination of these technologies

We also have, with each method available, a potential for some or all of the following problems:

- high capital cost per sub
- customer access to secured programming
- operator owned equipment in home
- field installation
- VCR/cable ready interface

The following addressable tap technology options are currently available:

Basic service (all band) switch.
Basic service plus x pay tiers (eg; low, mid, high, super, hyper).
Basic plus tiers plus descrete channel control.

Hybrid systems(addressable tap plus addressable descrambler):

Addressable Basic plus encrypted pay/PPV.
Addressable Basic plus addressable pay plus encrypted PPV.

If we examine several of these options on a capital cost vs flexibility basis, we may see that the obvious solution is not necessarily the best solution.

Addressable scrambling. The most widely employed CATV control technology is the addressable scrambling system. FIG (1)

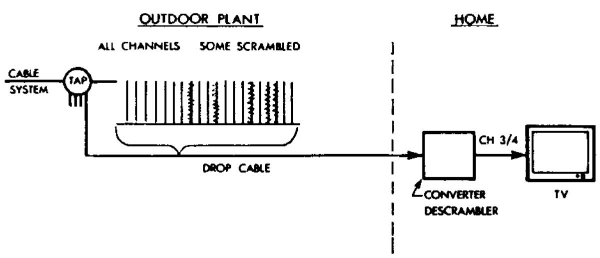

FIG.(1) ADDRESSABLE DESCRAMBLER TECHNOLOGY

These systems are quite similar in concept and end result, although the technologies involved vary widely between manufacturers. There are, however, several parameters which are relatively universal: These are:

- Scrambling usually requires little or no modification to existing plant.

- Scrambled services are brought into the customer's home along with basic cable service.

- Expensive operator owned equipment is installed inside the customer home.

- Descramblers are largely incompatible with customer equipment such as; cable ready TV's stereo television, and programmable VCR's.

Off premises converters. A natural development of the addressable scrambling approach was to move the operator owned converter out of the customer's home. FIG (2)

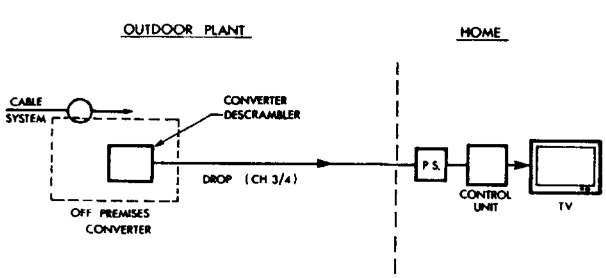

FIG.(2) OFF PREMISES CONVERTER

While at first glance, this may seem to be a solution to some of the problems posed by addressable scrambling, there are new limitations imposed by this technology. Among these are:

- A requirement to install at least the support structure (housings, power supplies, etc.)for all homes passed in the system.

- A requirement to separate the addressable descrambler/converter, so as to leave the channel selection circuit in the customer's home.

- A requirement to duplicate hardware in order to serve multiple televisions.

- System is still incompatible with most customer owned equipment.

Full function addressable tap. Many operators have found that addressable tap technology can solve many of the problems encountered with off premises converter system. FIG (3)

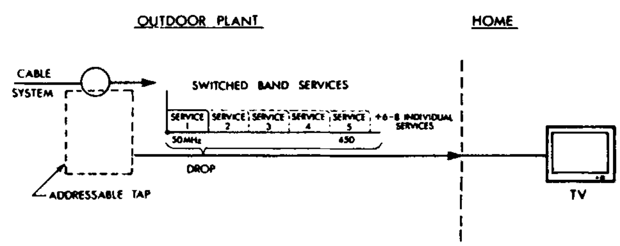

FIG.(3) FULL FUNCTION ADDRESSABLE TAP

The addressable tap is considerably less complex than the off premises converter with the following particular advantages:

- No operator owned equipment in the customer's home, except leased low cost converter if required.

- Full cable ready and VCR compatibility.

- No disconnect/reconnect or equipment recovery manpower costs for basic service cusomters.

- No customer access to either secured programming or converter control interfaces.

- Particularly adaptable to high churn and transient residential areas (apartment etc).

Hybrid system. The use of a combination of technologies can provide better security/flexibility/cost performance than single technologies in some cases. In particular, the combination of a limited function addressable tap with addressable descramblers for pay service can have advantages in both operating cost and security. In this system FIG (4), access to all programming is secured via addressable tap.

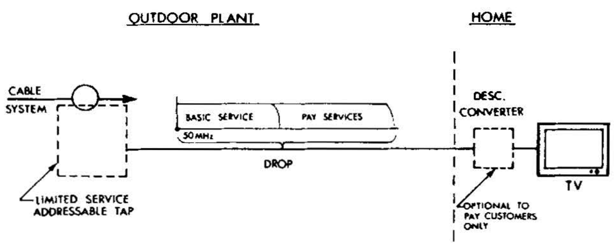

FIG.(4) HYBRID ADDRESSABLE / SCRAMBLE

Even basic service customers do not receive encrypted pay services. Pay reception requires both a descrambler from the operator, and the activation of the pay service tap. While this system retains some of the difficulties of normal addressable scrambling systems (i.e. operator equipment in the home) it does offer several distinct advantages. In particular:

- No service costs for basic reconnect/disconnect.

- No access to secured programming by non pay TV customers.

CAPITAL COST ANALYSIS OF VARIOUS CONTROL TECHNOLOGIES

In order to properly analyze the comparative costs of various control technologies, it is necessary to examine several different customer applications. The following comparison deals with four different technologies under eight basic applications:

- Off Premises converter

- Full Function addressable tap, including converter where required

- Basic function (Basic plus pay TV) tap, including descrambler were required

- Addressable descrambler

The following applications are analyzed.

1 BASIC	1 BASIC Cable Ready TV
2 BASIC	2 BASIC Cable Ready TV
1 PAY	1 PAY Cable Ready TV
2 PAY	2 PAY Cable Ready TV

The comparison assumes 50% penetration of basic, where the support structure (housings, power supplies etc) are installed for 100% homes passed, and amortized over the actual penetration.

The following representative prices were developed from market analysis, and were employed in the comparison.

- Off premises converter	$290-340 per drop.
- Full function addressable	$230
- Basic function tap	$ 60
- Addressable descrambler	$100
- Basic converter	$ 50
- Basic tap and hardware	$ 10

As can be seen by the comparison graphs FIG (5) & (6) the effect of various applications can show dramatic variation in capital cost depending on technology employed.

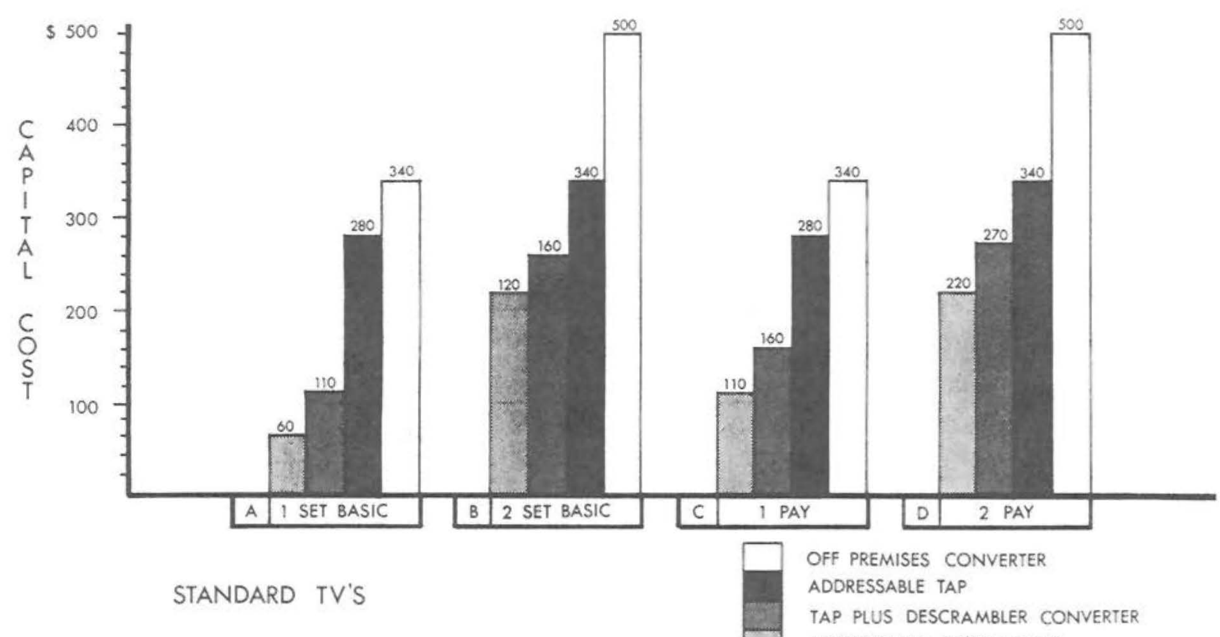

FIG. (5)

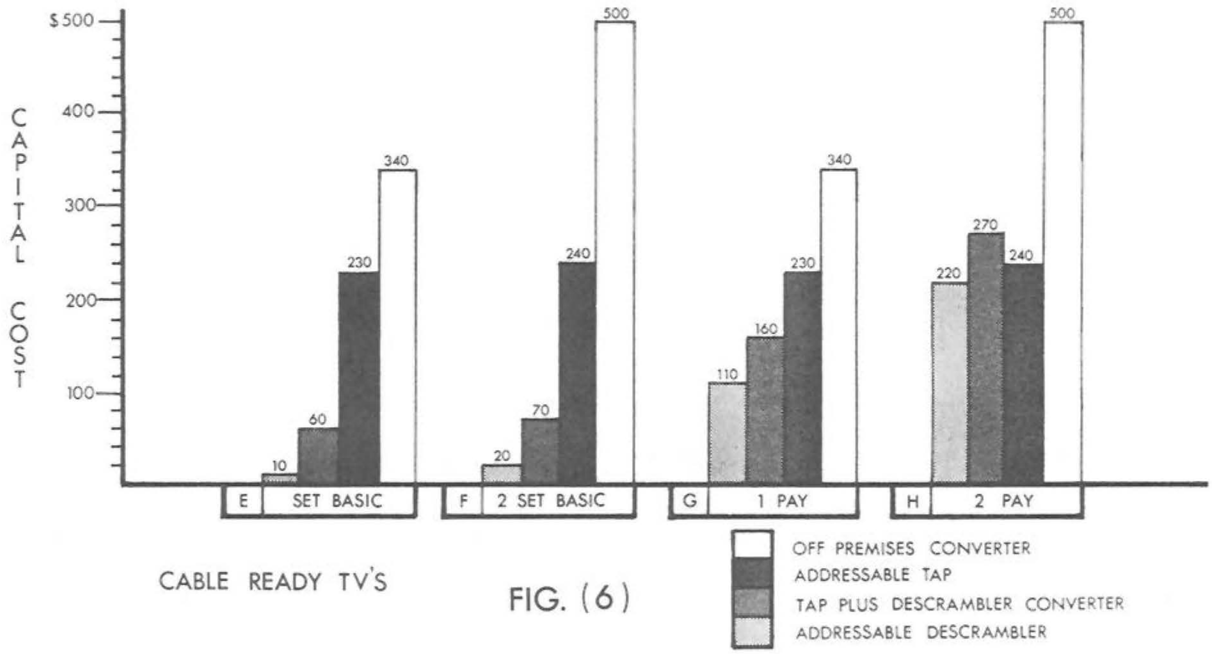

FIG. (6)

Of particular note are the following;

In comparison of column (A) & (B):

1. The capital cost increase from single to dual outlet varies from $60.00 to $160.00, depending on the technology.

2. The actual capital cost for two basic sets varies from $120.00 to $500.00. In the basic service application, both the off premises converter and the addressable tap have much higher cost due to having the pay service capability built in. This can be seen in column (C) and (D) where no increase is shown for addition of pay services with these technologies.

A major difference in the cost effectiveness of technologies can be seen by comparison of FIG (5) & (6) where the effect of cable ready TV's is examined.

It can be seen that all technologies except off premises converters take some advantage from cable ready TV's in the Basic service application (column E,F).

In the pay service modes (column G,H) only the addressable tap system gains a cost advantage from cable ready sets.

OBSERVATIONS

The most significant observation from the analysis are:

- The combined addressable tap/descrambler systems compares favorably to the addressable descrambler system cost with the benefit of much higher security.
- As both penetration of pay service, and penetration of cable ready sets increase, the cost effectiveness of full function addressable tap systems increases.
- Off premises converter systems gain no advantage from cable ready TV's or multiple set connections.

ACKNOWLEDGEMENT: Financial Information Provided By

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ON THE USE OF HIGH EFFICIENCY POWER SUPPLIES

Dan Pike

PRIME CABLE CORP.

ABSTRACT

The effects of recent developments in power supply efficiency are examined, with particular emphasis on operating costs.

INTRODUCTION

In recent years rapid developments in semiconductor technology and computer memory requirements have led to some rapid advancements in power supply technology, particularly switching regulated supply technology. The linear series pass designs were too bulky and inefficient for those applications. For personal computers, peripherals and many other consumer and industrial applications small highly efficient power supplies were developed. Many of these units operate in the same ranges of voltage and power that amplifier stations in use in the CATV industry require, and lately some of these advanced designs have been applied to the CATV industry. It is particularly important to note that the efficiency of these supplies has a very significant impact on the operating costs of a cable television system.

RECENT ADVANCEMENTS

Today it is commonplace to see power supply efficiency in the mid-eighties and the present state-of-the-art of switching power supplies for the ranges of concern to the cable industry is about 90%. Traditionally, the series pass units used in many trunk stations and virtually all line extender stations operated in the range between 40 and 60% efficiency. The switching regulated supplies used in some trunk stations approach 70% but their use is limited to the trunk lines.

The recent achievements in efficiency are due to advancements in all switching architectures but particularly those involving off-the-line or transformerless topologies. They typically use highly optimized magnetics and power MOSFET devices, with elaborate sensing and control circuits.[1] These have gained a great deal of respect for price efficiency and reliability without forfeiture in key parameters of concern to the cable industry such as susceptibility to transients and isolation.[2,3] Developments continue at a strong pace in this area[4,5] and the cable industry can expect to take advantage of reliable, efficient designs in power supplies that develop from proven techniques in other industries where these supplies sell in the 50¢ per watt range.[6] Judicious design effort and attention to the advancements in other industries can achieve for our industry the benefits of these supplies while minimizing their disadvantages of ripple, EMI, and increased circuit complexity.

CASE STUDIES

The loading presented by CATV amplifiers to their central supply is represented by a complex piece-wise nonlinear network,[7] and attempts to judge the items of interest for this study are better done empirically. While others [8,9] have pointed out the advantages of careful attention to the original loading calculations and equipment selection, the present day effects of the highly efficient power supply is worth examining. Such an architecture has been employed in a CATV product with a successful history of about three years[10] and others now or soon will be offered to the industry[11].

Some test designs were done on large and varied samples of plant to see the significance of these power supplies when used in various applications typical of the industry. The results were quite favorable in every case.

Case 1 shows the influence of the high efficiency supplies when used in a typical urban plant. The influence of the high efficiency supplies is given for several criteria, but the one of most importance is that a 34% reduction in power costs is achieved. The comparison is one of a complete series regulated supply to a high efficiency unit and a number of typical operating variables might be influential in raising or lowering that percent savings. A plant with a higher feeder to trunk ratio would see a higher benefit since 60% of the power consumption in this case was in the line extenders. It is the power consumption of the line extender which has the greater effect on I^2R losses in the feeder cable, and the power lost in the power supply can equal or exceed the power required for the amplifier modules. Accordingly, it is in the feeder amplifiers where these power supplies can achieve their greatest savings.

In Case 2, an upgrade application is modeled and it is particularly important to note a 24% reduction in power usage even though the trunk line had been refitted with feedforward amplifiers and the actives count had been increased due to the necessary corrections required in such an upgrade.

Case 3 shows the contribution of the trunk and feeder system to the total reduction in power usage by the use of the higher efficiency supplies. The case shows a total reduction of power required of 30%, with the contribution of each section about 15%. This suggests that there are significant cost reductions still possible in the improvement of a trunk switching supply from present efficiencies, and also shows the significance of improving the line extender supply efficiency.

THE RELATIVE SIGNIFICANCE FOR CATV OPERATIONS

As the industry becomes more mature with fewer chances for new growth, continued improvements in operating efficiency are sought. Minimizing plant power costs represents a very significant opportunity for improvements to the operating margins of a cable company because power costs can easily approach 10% of the total direct operating expenses and 1 to 2% of the total expenses involved in the operation of a cable television plant. A 30% reduction in those expenses is quite significant. Assuming a pessimistic incremental cost estimate of $50 for a line extender supply and $100 for a trunk station supply and a power cost of 10¢ per kilowatt hour (slightly above the 8¢ per kilowatt hour national average), the results in Case 1 can be used to forecast about a 12 month simple payback for the additional costs incurred in the equipment. At costs of 12 to 15¢ per kilowatt hour (closer to typical urban plant costs) the payback reduces to 10 and 8 months. It is important to note that dual plants and higher bandwidth plants have an opportunity for much greater savings not to mention the effect of future power cost increases which grow steadily a few percent each year. It is interesting to note, however, that a return to solid copper center conductors would yield about a 15 year simple payback indicating clearly that the efficiency of the line extender supply is the major component to be dealt with. The simple paybacks suggest that initial cost alone is not the dominant feature in the selection of new equipment, and that among the more complex considerations of a rebuild that power supply efficiency would take high priority.

Various comparisons of the relative significance of these savings would indicate that these potential savings alone approximate the total of various other but less controllable expense items such as vehicle expenses, plant maintenance, copyright fees and pole rental. Further, it is interesting to note that the magnitude of these cost reductions can have the same net effect to the cable company as the results of the marketing efforts.

CONCLUSIONS

Improvements in the ubiquitous power supply haven't kept up with other amplifier advancements in our industry and an application of presently available technology to those components can show reductions in power costs of 30% or greater, regardless of whether the application is in new or refit work. Power supply efficiency should become a key consideration in equipment selection and application.

ACKNOWLEDGEMENTS

Steve Williams, CATV Design Associates, selected and designed the models and provided other significant contributions to the paper.

CASE 1

HIGH EFFICIENCY POWER SUPPLY ADVANTAGE IN A TYPICAL URBAN PLANT

	POWER COST(1) PER MILE OF PLANT,$	ACTIVES PER SUPPLY	MILES OF PLANT PER SUPPLY	KWH PER MONTH(2)
Conventional	167.5	14.5	4	525
High Efficiency(3)	110.0	21.0	6	340

NOTES:

(1) Per year, assuming 10¢/kwh/month power cost.
(2) Per 60v power supply area, average.
(3) High efficiency assumes 85% efficiency on all actives; conventional used current specifications on series regulated power supplies for all actives.

CONDITIONS: 400 MHz; active reverse; single cable.

Design Sample:	100 miles
Density:	112 h/m
Cables Used:	750/500; 3rd generation GID
Feeder/Trunk Ratio:	3/1
Actives:	103 trunk; 248 line extender
Power Supply Loading:	80% of maximum

CASE 2

HIGH EFFICIENCY POWER SUPPLY ADVANTAGE IN AN UPGRADE APPLICATION

	KWH PER MONTH(1)	ACTIVES PER MILE(2)
Conventional	577	2.5
High Efficiency(3)	438	3.0

NOTES:

(1) Per 60 volt power supply area, average.
(2) Actives increase due to some necessary distribution rearrangement and corrections required to accommodate 300 MHz loading.
(3) High efficiency assumes 85% efficiency on all actives; conventional used current specification on series regulated power supplies for all actives.

CONDITIONS: 220 MHz plant upgraded to 300 MHz (single cable). Trunk amplifiers were changed to feedforward units.

Design Sample:	100 miles
Density:	52.3 h/m
Cables Used:	750/500; 3rd generation GID
Feeder/Trunk Ratio:	4.5/1
Actives:	220 MHz; 47 trunk; 207 line extenders 300 MHz; 57 trunk; 242 line extenders
Power Supply Loading:	80% of maximum

CASE 3

TRUNK VS TOTAL SYSTEM ADVANTAGE

	KWH PER MONTH(1)	NUMBER OF POWER SUPPLY AREAS(1)
Conventional	4,421	9
Trunk High Efficiency(2)	3,754	8
Total System High Efficiency	3,097	6

NOTES:

(1) For the total plant.
(2) High efficiency assumes 85% efficiency on all actives; conventional used current specification on series regulated power supplies for all actives.

CONDITIONS: 400 MHz; active reverse, single cable.

Design Sample:	37.5 miles
Density:	46 h/m
Cables Used:	750/500; 3rd generation GID
Feeder/Trunk Ratio:	3.4/1
Actives:	36 trunk; 89 line extenders
Power Supply Loading:	80% of maximum/ 400 MHz with active reverse.

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OPTICAL FIBER SUPER-TRUNKING

The Time Has Come
A Performance Report on a Real-World System

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American Television & Communications, Corp.

ABSTRACT

A review of a specific application for video interconnection on single-mode optical fiber over a 13.9 mile path, covering system design, aerial and underground plant construction, terminal equipment selection, and operating results. Both digital and analog circuits are used in the system, and the economics and performance of the two approaches are compared. The digital equipment installed transports 4 video channels on a single-mode fiber using both 1300nm and 1550nm lasers, and the analog system is tested transporting both 8 and 12 channels per fiber. To explore the potential of the system, tests are run on a fiber path 27.8 miles (44.7km) in length. Using actual costs, an updated economic comparison between fiber optic systems and FM video coaxial systems is made.

The conclusion is drawn that analog fiber video transmission systems have been developed to the point where they offer economics and performance generally superior to, and reliability substantially better than, FM video coaxial systems. Both analog and digital fiber systems are shown to be capable of excellent quality video transmission through a path loss of over 25dB.

INTRODUCTION

The technology to make optical fiber super-trunking a practical, economical option for CATV system interconnection and other video signal transportation applications is here. Such systems are significantly more reliable than other options due to the practicality of very long, totally passive links. In an increasing number of cases, they are actually less expensive than the more traditional alternatives: microwave and FM video on coaxial cable. This paper is intended to document the construction of such a system and to draw conclusions from the performance results and economics which emerged. It is hoped that this will make the optical fiber option more accessable to the CATV industry.

In 1985, this author published a report in the NCTA Technical Papers outlining fiber basics for CATV applications and providing economic and performance comparisons between FM coaxial cable, and analog and digital single-mode fiber optic video transmission systems. The conclusions, based on the information available at that time, indicated clear advantages for each of these three technologies, but indicated that as the optical fiber field continued to mature, the balance would shift in favor of the fiber approaches. That has, to some extent, happened, as will be demonstrated through the experience documented here.

PLANNING & DESIGN

Planning

Oceanic Cablevision, Inc., currently serves 165,000 cable homes on the Island of Oahu in Hawaii. The acquisition and assimilation of an adjacent cable system made it necessary to provide an interconnection between Oceanic's headend and the new system. Because of local advertising insertions, tape importation of signals not available from satellite, tape-delay of satellite signals, and the lack of high-quality off-air reception due to an intervening mountain range, it was necessary to transport virtually all of Oceanic's signals to this system. An FM video coaxial trunk existed over part of the route, but it had insufficient channel capacity and was plagued with frequent power outages of long duration in the mountainous rain forests through which it passed. Microwave was not a serious option because of the lack of sites for a route of less than 3 hops.

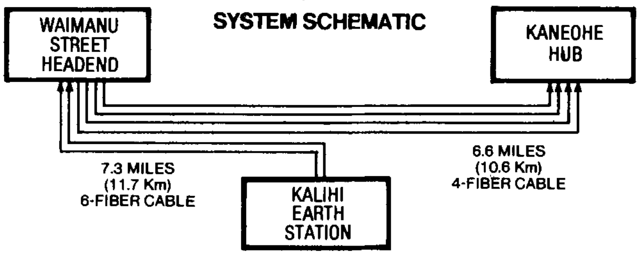
The logical route for this new interconnection passed Oceanic's earth station facilities. An FM coaxial super-trunk had been in use for some years to connect this facility with Oceanic's headend, and that trunk was in need of substantial additional capacity.

These factors combined to make a multiple-fiber single-mode optical trunk attractive to provide highly reliable capacity for transportation of additional signals from the earth station to Oceanic's headend, and of all of Oceanic's channels to the new system. The schematic in

Figure (1) demonstrates the configuration of the planned system. Two fibers were to be used to provide additional capacity from the Kalihi earth station to the Waimanu headend, and four fibers to provide signal carriage to Kaneohe, the primary hub of the newly acquired cable system.

< *Figure 1* >

SYSTEM SCHEMATIC

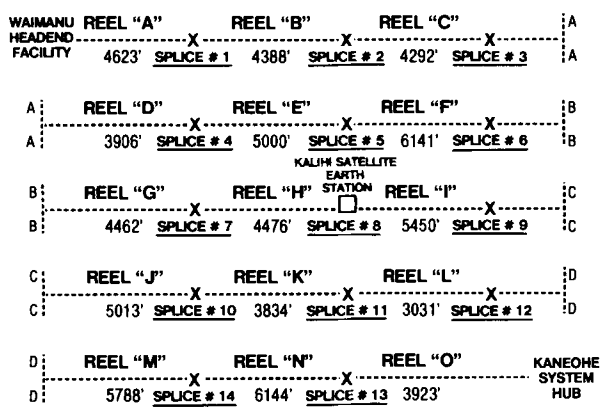


Design

The distance to be traversed was 13.9 miles (22.3km), and a design power budget was created. One necessary element in developing a power budget is a knowledge of the number of splices. Physical locations and underground pulling conditions were taken into account in selecting the splice locations, while keeping fiber reel lengths long. Figures (2) and (3) show the splice locations, and the fiber cable reel lengths which were ordered. Additional footage was ordered on each reel to allow for vertical riser pole runs, and to provide slack to make fusion splicing easier. This extra footage could also be pulled through the system to simplify repair splicing, should the system be cut in the future. The fiber order specified reel lengths to a tolerance of -0%, +5%.

< *Figure 2* >

SPLICE LOCATION DESIGN



< *Figure 3* >

FIBER ORDERING LIST

REEL USE LOCATION	STRAND LENGTH	REEL #	REEL LENGTH ORDERED	REEL LENGTH RECEIVED
Waimanu Street to Splice #1	4623'	A	4825'	5032'
Splice #1 to Splice #2	4388'	B	4600'	4808'
Splice #2 to Splice #3	4292'	C	4500'	4858'
Splice #3 to Splice #4	3906'	D	4125'	4461'
Splice #4 to Splice #5	5000'	E	5400'	5776'
Splice #5 to Splice #6	6141'	F	6575'	7013'
Slice #6 to Splice #7	4462'	G	4850'	5143'
Splice #7 to Earth Station	4476'	H	4900'	5264'
Earth Station to Splice #9	5450'	I	5650'	5720'
Splice #9 to Splice #10	5013'	J	5200'	5510'
Splice #10 to Splice #11	3834'	K	4100'	4339'
Splice #11 to Splice #12	3031'	L	3250'	3638'
Splice #12 to Splice #13	5788'	M	6000'	6570'
Splice #13 to Splice #14	6144'	N	6400'	7016'
Splice #14 to Kaneohe Hub	3923	O	4300'	4494

The power budget in Figure (4) reflects relatively conservative design. The budget assumes a splice loss of 0.25dB per splice; fiber loss of 0.4dB per kilometer both at 1300nm and 1550nm; connector loss at terminal equipment of 0.5dB per connector, and a total WDM diplexer loss of 6dB. The potential for future use of the same fiber at both 1300nm and 1550nm was considered an important factor. A total design path loss of 25dB, used in evaluating terminal equipment, allowed for a safe operating margin.

< *Figure 4* >

DESIGN POWER BUDGET: Waimanu Street to Kaneohe

	ANALOG (1300 nm)	DIGITAL (1300 nm)	DIGITAL (1550 nm)
Laser Output:	−3 dBm	−3 dBm	−5 dBm
Fiber Loss: 22.3 Km @ 0.4 dB/Km	8.9 dB	8.9 dB	8.9 dB
Splice Loss: 14 @ 0.25 Ea.	3.5 dB	3.5 dB	3.5 dB
Conn Loss: 2 @ 0.5 Ea.	1.0 dB	1.0 dB	1.0 dB
WDM Loss: 2 @ 3 Ea.	6.0 dB	6.0 dB	6.0 dB
TOTAL LOSS	19.4 dB	19.4 dB	19.4 dB
POWER INPUT	−22.4 dBm	−22.4 dBm	−22.4 dBm
MIN. RECEIVER INPUT	−28.0 dBm	−34.0 dBm	−34.0 dBm
SYSTEM MARGIN	5.6 dBm	11.6 dBm	9.6 dBm

Fiber Selection

The fiber cable to be used was selected on the basis of both cost and availability. Because of the fact that there was substantial demand for single-mode fiber from the telecommunications industry, availability was an especially important factor. A steel strength member was specified, along with loose buffering of the fibers, in pairs, in gel-filled polyethylene tubes. A Kevlar wrapping and an outer polyethylene jacket were specified, but no armor was required since the cable would not be direct-buried at any point. The same cable was specified for both aerial and underground portions of the route.

The cable which was selected cost approximately $1.05 per foot for the six fiber portions and $0.75 per foot for 4 fibers, which equates to about $0.60 per fiber-meter. The outside diameter of the cable was the same (0.46") in either case, with one buffer tube being replaced with a solid polyethylene cord in the 4-fiber cable. The manufacturer selected, Siecor Corporation, of

Hickory, N.C., agreed to a maximum loss specification of 0.4dB per kilometer at both 1300nm and 1550nm.

Equipment Selection

The terminal equipment selected for the first phase of the project (channels which were most urgently required) was digital. Although digital equipment costs were significantly higher than analog, there was digital equipment available which was reasonably competitive, could be delivered quickly, and in which there was a high degree of confidence in performance, based on other installations. This equipment was ordered from Quante Corporation, of Santa Clara, CA.

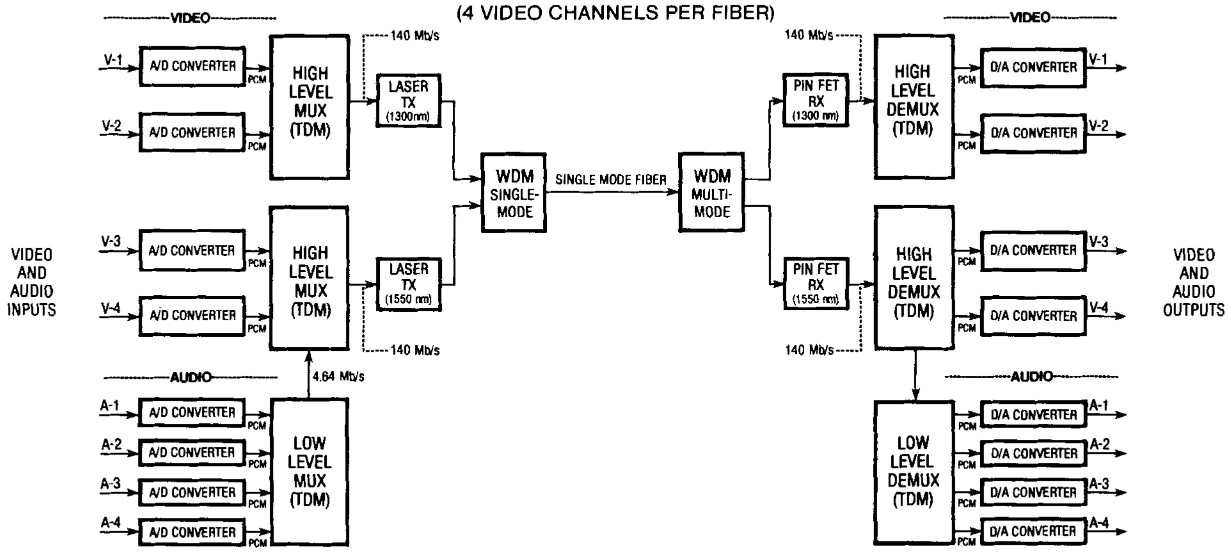
In the equipment specified, video is converted from analog to digital form with seven-bit encoding (providing 128-step amplitude resolution) and a 9.28MHz sampling rate, producing a data stream of 65MBits/sec. Audio is converted using 12-bit encoding (16-bit encoding is optional).

For the second phase of the project, providing the remainder of channels in the system, there was sufficient time to thoroughly explore analog transmission. Analog transmission was particularly attractive because it involved substantially less expensive terminal equipment, and could, with available equipment, transport significantly more video channels per optical fiber. In addition, frequency-modulated (FM) Frequency Division Multiplexed (FDM) analog video transmission on fiber is theoretically capable of excellent video performance. The primary concern with the technology was the potential effect of intermodulation products between the various FM sub-carriers due to non-linearities in both the laser and detector systems. Because of these concerns, a demonstration was arranged by the equipment vendor with the assurance that eight video channels per fiber would be delivered over a 25dB path within RS250B (medium-haul) video transportation specifications.

The manufacturer chosen was Synchronous Communications, Inc., of San Jose, CA.. The equipment specified uses 8MHz peak deviation frequency-

< Figure 5 >

DIGITAL VIDEO FIBER TRANSMISSION SYSTEM
(TDM/WDM)
(4 VIDEO CHANNELS PER FIBER)



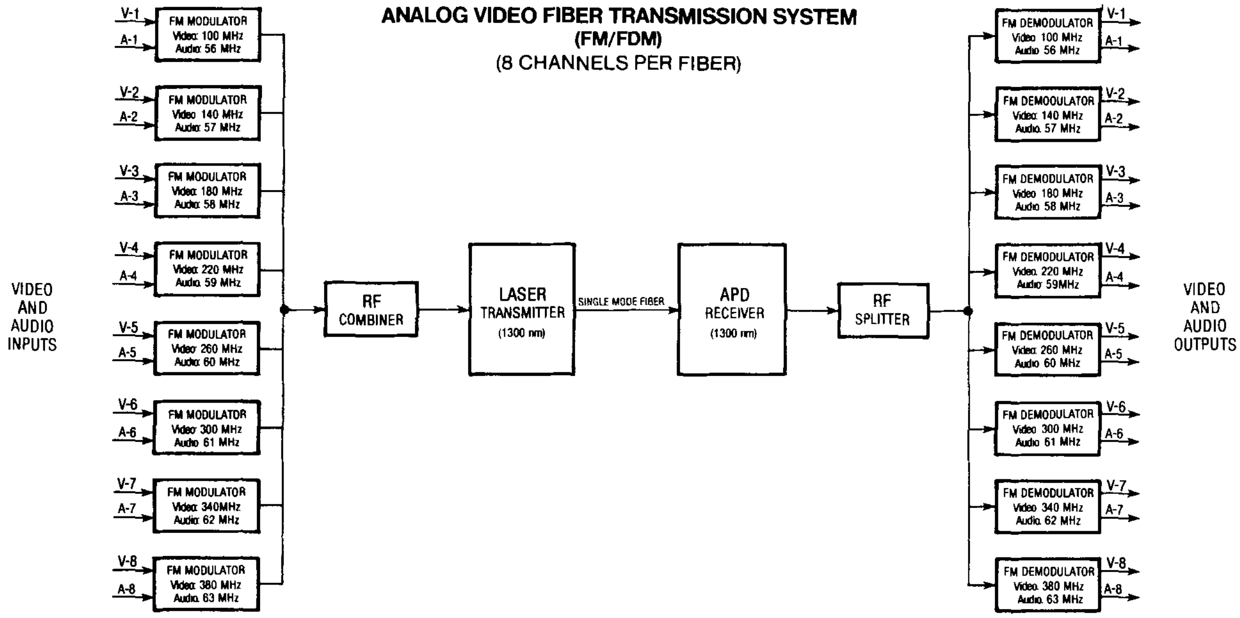
Two video channels and up to 8 audio channels (or 16 RS-232 signals) are Time Division Multiplexed (TDM'd) together into a 140 MBit/sec. data stream. As Figure (5) demonstrates, data streams (each including two video channels and associated audio signals) are applied to one 1300nm laser and one 1550nm laser. The outputs of the two laser are combined optically in a process termed "Wavelength Division Multiplexing" (WDM), and the resulting two optical carriers, containing four video signals, are transported on one single-mode fiber. At the receive end, signals are optically separated, received with PIN-FET detectors and demultiplexed, and the base-band signals recovered. The equipment uses Lasertron lasers and QLT PIN-FET receivers. This entire process involves well understood technology and the equipment has essentially no adjustments.

modulated video carriers, and separate frequency-modulated aural carriers. The system uses Hitachi 1300nm lasers and Fujitsu avalanche photo-diode (APD) detectors. Figure (6) shows a block diagram of the system.

The vendor dealt with intermodulation concerns in two ways. By, using very wide deviation FM, a high carrier-to-interference toleration was to be obtained. It was expected that second-order intermodulation products would have a greater effect on this system than third and higher-order products at the laser operating point selected. A frequency plan was devised whereby the center frequencies of all second-order products would fall precisely between channels. The frequency plan is illustrated in Figure (7). The channels are 40Mhz wide and channel center-frequencies are

< Figure 6 >

ANALOG VIDEO FIBER TRANSMISSION SYSTEM
(FM/FDM)
(8 CHANNELS PER FIBER)



located at (N x 40)-20MHz, where N is the channel number. Thus, channel 1 would be at 20MHz, channel 2 would be at 60MHz, etc. Channels 1 & 2 were to be devoted to aural carriers, which were to be carried at levels 20dB lower than the video carriers on the system.

In this frequency plan, all additive and subtractive second-order intermodulation products will have center frequencies between channels. Thus, the additive product of channel 3 (100MHz) and channel 4 (140MHz) will fall at 240MHz, between channel 6 at 220MHz and channel 7 at 260MHz. The subtractive product between channels 3 & 4 will fall at 40Mhz, between channels 1 & 2. The effect of energy falling within a channel is proportional to the distance of the interfering signal from the center frequency of that channel. Much of the power in the second-order intermodulation products would be near their center frequencies, although these products would have a peak deviation of twice the frequency of the fundamentals, and would have energy within both adjacent channels. Figure (8) shows some of these second-order products in the spectrum.

The strength of the intermodulation products would ultimately be a result of the non-linearity of the optical devices used, but it was predicted that through this frequency plan, their effect could be minimized well below the point of visibility.

There is a temptation in frequency planning to assume that intermodulation products behave like CW carriers. Because they are the product of 2 or more frequency-modulated carriers, the deviation of the second-order products is twice that of the main carriers, and the peak deviation of higher order products is proportionately higher. While it is desirable to avoid having intermodulation product center frequencies fall in-band, it must be recognized that significant side-band energy will fall there regardless of the frequency plan. Thus, while frequency planning cannot be ignored, it is higher deviation (along with more linear optical devices) which holds the key to high performance FM/FDM fiber transmission systems.

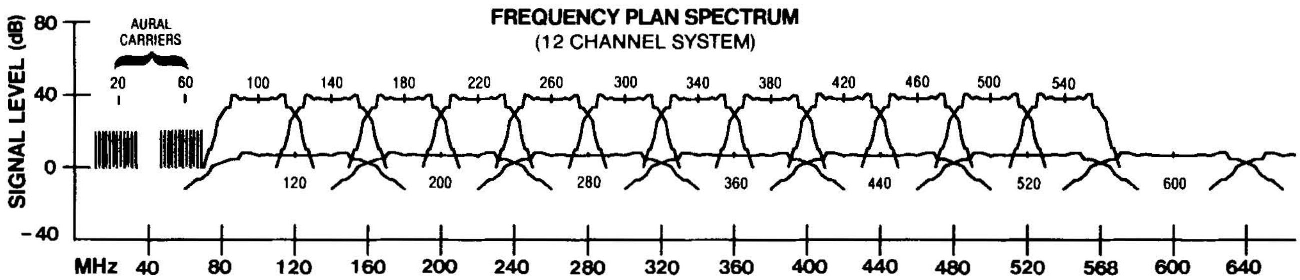
< Figure 7 >

FREQUENCY PLAN CALCULATIONS

Channel Center Frequencies shown in bold face type
2nd Order Center Frequencies shown in light face type

CH#	FREQ.	2nd ORDER INTERMODULATION COMBINATIONS
1	**20 MHz**	
	40 MHz	2−1, 3−2, 4−3, 5−4, 6−5, 7−6, 8−7, 9−8, 10−9, 11−10, 12−11, 13−12, 14−13
2	**60 MHz**	
	80 MHz	3−1, 4−2, 5−3, 6−4, 7−5, 8−6, 9−7, 10−8, 11−9, 12−10, 13−11, 14−12, 1+2
3	**100 MHz**	
	120 MHz	4−1, 5−2, 6−3, 7−4, 8−5, 9−6, 10−7, 11−8, 12−9, 13−10, 14−11, 1+3
4	**140 MHz**	
	160 MHz	5−1, 6−2, 7−3, 8−4, 9−5, 10−6, 11−7, 12−8, 13−9, 14−10, 1+4, 2+3
5	**180 MHz**	
	200 MHz	6−1, 7−2, 8−3, 9−4, 10−5, 11−6, 12−7, 13−8, 14−9, 1+5, 2+4
6	**220 MHz**	
	240 MHz	7−1, 8−2, 9−3, 10−4, 11−5, 12−6, 13−7, 14−8, 1+6, 2+5, 3+4
7	**260 MHz**	
	280 MHz	8−1, 9−2, 10−3, 11−4, 12−5, 13−6, 14−7, 1+7, 2+6, 3+5
8	**300 MHz**	
	320 MHz	9−1, 10−2, 11−3, 12−4, 13−5, 14−6, 1+8, 2+7, 3+6, 4+5
9	**340 MHz**	
	360 MHz	10−1, 11−2, 12−3, 13−4, 14−5, 1+9, 2+8, 3+7, 4+6
10	**380 MHz**	
	400 MHz	11−1, 12−2, 13−3, 14−4, 1+10, 2+9, 3+8, 4+7, 5+6
11	**420 MHz**	
	440 MHz	12−1, 13−2, 14−3, 1+11, 2+10, 3+9, 4+8, 5+7
12	**460 MHz**	
	480 MHz	13−1, 14−2, 1+12, 2+11, 3+10, 4+9, 5+8, 6+7
13	**500 MHz**	
	520 MHz	14−1, 1+13, 2+12, 3+11, 4+10, 5+9, 6+8
14	**540 MHz**	
	560 MHz	1+14, 2+13, 3+12, 4+11, 5+10, 6+9, 7+8

< Figure 8 >



Connector Selection

Connections for the system were to be fusion splices except at the terminal points, where final connection to equipment would be through WECO biconical bulkhead connectors. These connectors, while introducing significant loss and adding a certain element of unrepeatability to overall path loss, would provide points for testing and trouble shooting the system. From these points an optical time domain reflectometer (OTDR) could be used to precisely locate any future cable break.

CONSTRUCTION

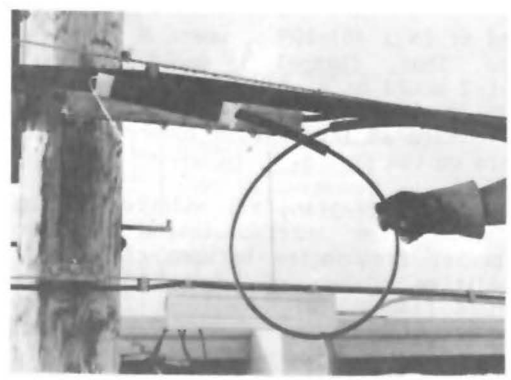
Underground Construction

All underground cable runs were located in existing conduits, either those leased from Hawaiian Telephone Company (a GTE subsidiary) or those owned by Oceanic Cablevision. In addition, most underground fiber cable was located within a "sub-duct" inside the conduit. The sub-duct used was made of polyethylene and had an I.D. of 3/4". This system of construction allowed for the placement of the sub-duct prior to fiber pulling, and any problems with conduit congestion and blockage were dealt with in advance. The fiber cable was then pulled through a completely clear path. In addition, should additional cables be pulled through these same conduits in the future, the sub-duct will provide protection for the optical fiber cable. The cost of the sub-duct was approximately $0.07 per foot.

The presence of the sub-duct made low-tension pulling relatively easy; linemen were stationed at various manholes and, with radio coordination, manually pulled the fiber into place. In this way, high pulling tensions were avoided. Once the pulling was complete, sub-duct sections were spliced using heat-shrink tubing. Figure (9) illustrates the use of such sub-duct in a section of aerial plant.

Because the cable was received on reels up to 2 kilometers in length, in most instances pulling a span from the center made more sense than pulling the entire length from one end. First, half of the span was pulled into place from the reel. Then, the remaining cable was pulled from the reel into a figure-eight shape on the ground as shown in Figure (10). After all the cable was pulled off the reel, the remainder of the span was pulled from the center, out of the figure-eight. The toughness of the fiber cable, especially when compared to aluminum-sheathed coaxial cable, was dramatically illustrated when one homeowner insisted on driving over the cable because her driveway was partially blocked. There was absolutely no visible or measureable mechanical or optical damage to the cable or any of the fibers that passed through that section.

< Figure 9 >



< Figure 10 >

Aerial Construction

One portion of aerial plant was built using standard over-lash techniques, with cable being pulled from a reel through rollers hung on an existing strand. There were no difficulties with this familiar method of construction or with the fiber cable that was handled in this way. Another portion of the system involved plant which was primarily aerial, but which followed a rather tortuous path of radical bends and short underground sections in an urban area. In this area, sub-duct was over-lashed to existing strand and coaxial cables, and was passed down riser poles and through underground sections. The fiber cable was then manually pulled as described previously. This construction method, while slightly more expensive than direct over-lash, provided easy pulling of full reel lengths and will provide for greater ease of repair should a section require removal, since the fiber cable can be pulled once again through the sub-duct.

Splicing

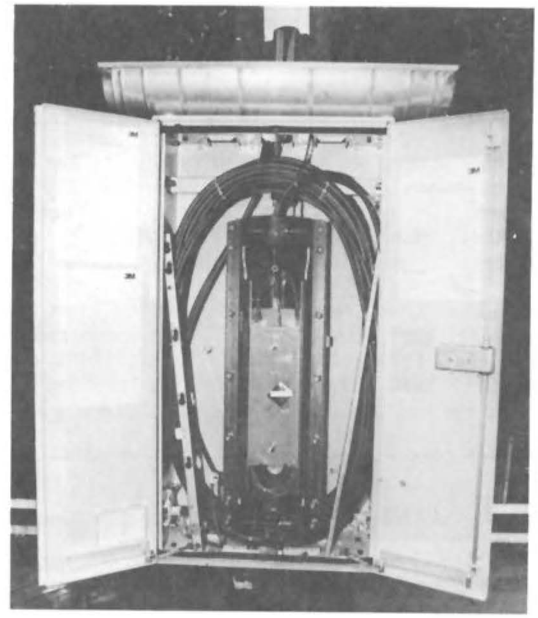
All fusion splicing and fiber testing was subcontracted to Hawaiian Telephone Company, since they had fusion splicing equipment, an optical time domain reflectometer, and trained personnel. This proved to be very satisfactory. As illustrated in Figure (11), all splicing was performed in a closed van. This was made possible by the slack which had been left at each splice location. A

< Figure 11 >

< Figure 12 >

laser injection/detection (LID) system was used to couple a small amount of light into each fiber being spliced, and to detect it on the other side of the splice. This allowed optimization of positioning prior to fusing. Underground splices were organized and sealed within a splice housing as shown in Figure (12). In many locations, these splices had to be located below ground level. Figure (13) shows the type of pole-mounted cabinet, splice housing, and splice organizing tray used in aerial sections of plant.

< Figure 13 >

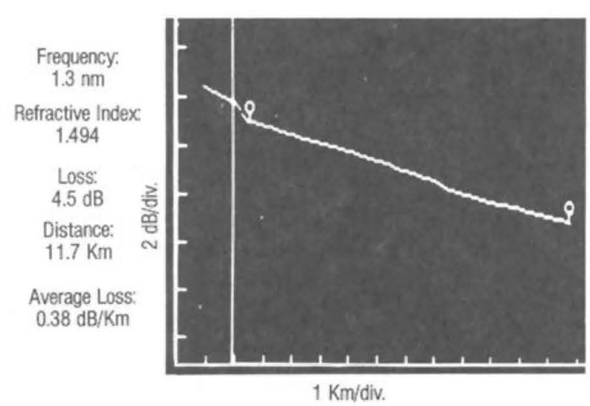


SYSTEM PERFORMANCE

Fiber Proof of Performance

Figure (14) shows an optical time domain reflectometer display of one of the 11.7km fibers from the earth station to the Waimanu Street headend. The total loss is 4.5dB. Figure (15) shows splice loss in one fiber over the route from Waimanu Street to Kaneohe, as well as the actual fiber loss. It should be noted that the average loss per splice was 0.078dB rather than the 0.25dB design specification used. These results are determined by the geometry of the single-mode core

< Figure 14 >



< Figure 15 >

FIBER AND SPLICE LOSSES

(22.3 Km / 14 SPLICES)

	AVG. LOSS	MAX. LOSS	TOTAL LOSS
1300 nm FIBER LOSS	0.36 dB/Km	0.4 dB/Km	8.05 dB
1300 nm SPLICE LOSS	0.08 dB/splice	0.34 dB	1.12 dB
1550 nm FIBER LOSS	0.22 dB/Km	0.29 dB/Km	4.91 dB
1550 nm SPLICE LOSS	0.05 dB/splice	0.29 dB	0.69 dB

within the fiber, as well as the time spent optimizing each splice. These numbers probably could have been improved slightly, but the fact that they were dramatically better than the design specification made this unnecessary.

Figure (16) shows the actual power budget which was obtained in this system. When compared with Figure (4), it is clear that the original design was over-conservative. With experience, more realistic design specifications should emerge.

< Figure 16 >

ACTUAL POWER BUDGET: Waimanu Street to Kaneohe

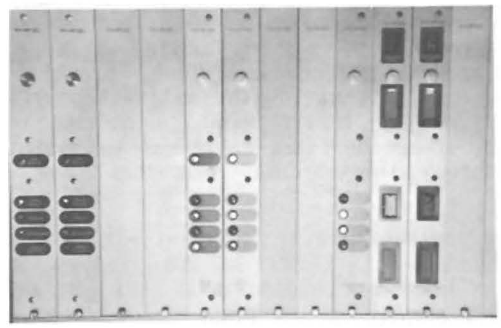
		ANALOG (1300 nm)	DIGITAL (1300 nm)	DIGITAL (1550 nm)
	Laser Output:	−2.8 dBm	−1.9	−6.3
Fiber Loss:	22.3 Km	8.1 dB	8.1 dB	5.0 dB
Splice Loss:	14	1.1 dB	1.1 dB	0.7 dB
Conn Loss:	2	1.0	1.0	1.0
WDM Loss:	2	6.0	6.0	6.0
	TOTAL LOSS	16.2 dB	16.2 dB	12.7 dB
	POWER INPUT	−19.0 dBm	−18.1 dBm	−19.0 dBm
	MIN. RECEIVER INPUT	−28.0 dBm	−34.0 dBm	−34.0 dBm
	SYSTEM MARGIN	9.0 dBm	16.0 dBm	15.0 dBm

Performance – Digital Systems

Figure (17) shows the Quante digital terminal equipment installed in a rack. Performance tests for the digital system were performed with a system configuration as shown in Figure (18). Because the path loss was lower than expected, tests were done by connecting two fibers at the Kaneohe hub, and using fibers over and back as the test run. This provided a path loss of 20.9dB, with connectors, over a total distance of 27.8 miles (44.7km). Additional attenuation was inserted as shown for threshold measurements. Figure (19) shows the performance of the digital system versus the major video parameters in the RS250B (medium-haul) specification. Video signal-to-noise measurements in the digital system were performed with a Tektronix model 1430 noise test set, with a measurement limit of 59.5dB.

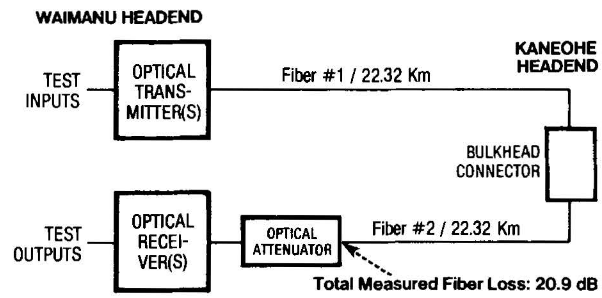
It is clear that the system meets most specifications. There are, however, compromises entailed in using 7-bit video encoding rather than the 8-bit encoding usual in broadcasting. While measurements indicated that the video signal-to-noise ratio was 60dB or better, a certain amount of quantizing noise was apparent in observing certain wave forms. This was, however, below the threshhold of perceptability. In the context of overall CATV system performance, this effect is not of great concern.

< Figure 17 >



< Figure 18 >

SCHEMATIC - TEST SETUP



< Figure 19 >

DIGITAL & ANALOG 20.9 dB LINK PERFORMANCE VS RS 250 B MEDIUM HAUL SPECIFICATIONS

PARAMETER		RS 250 B MED. HAUL	DIGITAL	ANALOG
SHORT TIME WAVE FORM DISTORTION LINE BAR EDGE OVERSHOOT		4 IRE PK-PK	2	2
CHROMA-LUM GAIN INEQUALITY		±.35 dB	0.25	0.2
DIFFERENTIAL GAIN		5%	2.5	4
DIFFERENTIAL PHASE		1.3°	1.3°	0.5°
GAIN FREQUENCY DISTORTION (MULTIBURST)	.5 MHz	±4 IRE AT EACH FREQ.	−1.5	0
	1.0 MHz		− .5	+1
	2.0 MHz		0	+1
	3.0 MHz		0	0
	3.58 MHz		−2.0	−2
	4.2 MHz		−2.5	−3
CHROMA NON-LINEAR GAIN DISTORTION	Small 20	±4 IRE	0	0
	Large 80	±1.6 IRE	-0.2	-0.2
CHROMA NON-LINEAR PHASE DISTORTION		2°	1°	0.5°
CHROMA-LUM INTERMODULATION 50 IRE REFERENCE		1 IRE	0	0
FIELD TIME DISTORTION		3 IRE PK-PK	1	0
DYNAMIC GAIN	Line Bar	±3 IRE		0
	Sync	±1.6 IRE		0
SIGNAL TO RANDOM NOISE (WEIGHTED)		60 dB	>59	8 CHS 63.9* 12 CHS 61.5*

*AVERAGE

The measured video signal-to-noise performance of the system did not change measureably as attenuation was added to the path. At an input level of -38dBm, audio "popping" began to become apparent and, with the rising bit error rate, video impairment became noticeable in the form of missing lines. The system was unusable as soon as these degradations appeared, and -38dBm was thus considered the effective receiver threshold of the system.

It has been shown that digital systems can carry more than four video channels per fiber through higher speed Time Division Multiplexing, although, currently, the cost per channel escalates rapidly. Limiting factors in the technology currently available are the speed of the logic, lasers and detectors. As higher speed logic becomes more economically available (particularly as the Gallium Arsenide logic family matures), it should become practical to carry more digital video signals on a single fiber using a single laser and detector, within the economic constraints of the CATV industry. It should also become less expensive to use 8-bit video encoding. It is expected that all of these factors will improve the economics of digital optical fiber video transmission, and will provide some improvements in performance as well. The technical performance of the digital system tested, was, however, quite satisfactory for CATV transmission purposes.

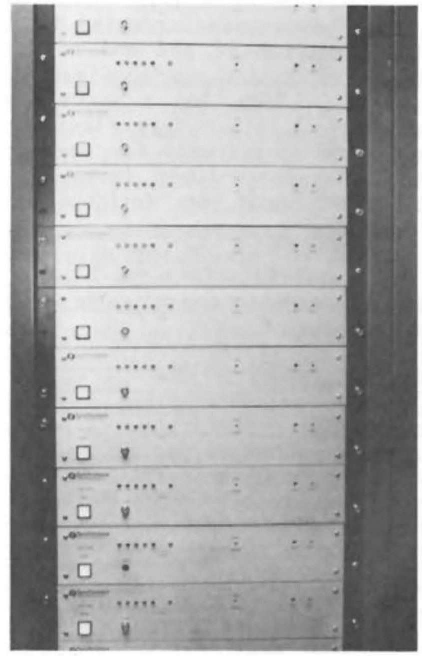
The conclusion was drawn that digital technology is presently capable of providing relatively high capacity, high quality video links over long distances. The optical margins available allow for systems with some branching loss. In addition, digital transmission lends itself very well to repeaters, with little compromise in signal quality, making very long-haul transmission practical. The Wavelength Division Mutliplexing technique demonstrated here also makes the two-way use of a single fiber a possibility, in a way directly analagous to frequency diplexed RF transmission in present coaxial systems.

Performance – Analog Systems

Figure (20) shows a photograph of the analog terminal equipment used. The test methodology was the same as illustrated in Figure (16) for the digital equipment, but measurements were also taken as a function of channel loading. Figure (19) shows the performance of this system versus the RS250B (medium-haul) specification, again with 20.9dB of path loss over 27.8 miles of fiber, and compares the results to the digital system. The system performed very satisfactorily, even when loaded with 12 channels. Video signal-to-noise ratio measurements in the analog system were performed with a Rohde & Schwarz model UPSF2 video noise meter.

Figure (21) shows, more specifically, the change in video signal-to-noise ratio performance as the system loading over the test path was raised from 8 channels to 12. The signal-to-noise performance, while remaining satisfactory, decreased as the number of channels was increased, with the resulting reduction in transmit power on each channel (the optical power output of the laser remained constant). These results were very encouraging with regard to carrying a large number of channels on a single fiber over long distances, with a high degree of transparency and reliability. All of these factors directly increase the number of applications where this technology will be economically practical in CATV systems.

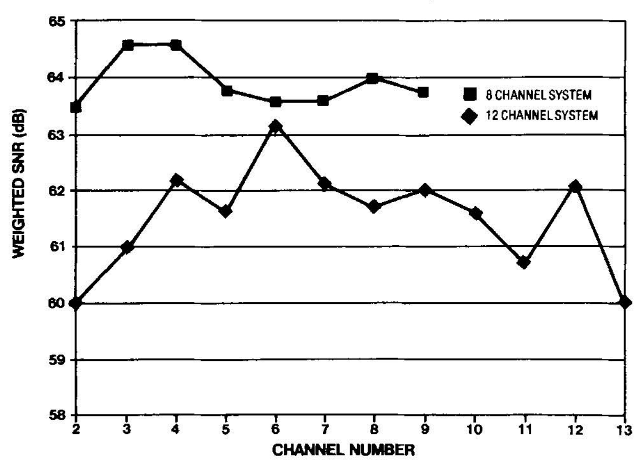
< Figure 20 >



< Figure 21 >

VIDEO S/N RATIO - 8 & 12 CHANNELS

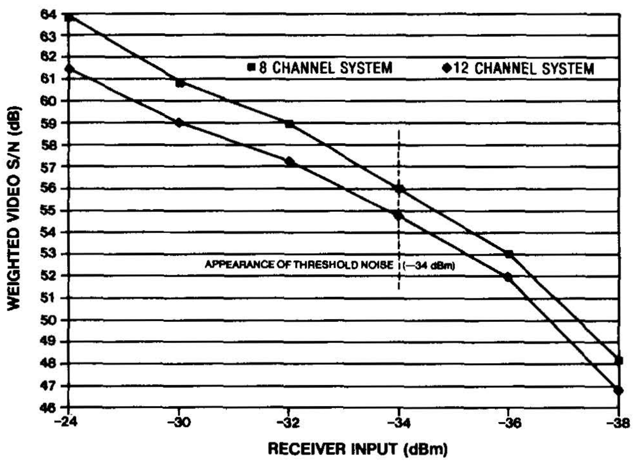
(APD INPUT: −24 dBm)



One critical test was the determination of the practical noise threshhold of the avalanche photodiode receiver. Figure (22) illustrates the result. While increased channel loading decreased video SNR performance somewhat, the same practical threshhold was observed in terms of APD input, regardless of channel loading, at approximately -34dBm. These tests were conducted by inserting additional attenuation at the end of the 20.9dB fiber path. The system as configured, with a laser output of -2.7dBm, has a maximum path loss to threshhold of 31.3dB. This figure is higher than expected and speaks well for the performance of the avalanche photo-diode detector, although practical systems must be designed with some operating margin.

< Figure 22 >

VIDEO S/N RATIO VS APD RECEIVER INPUT

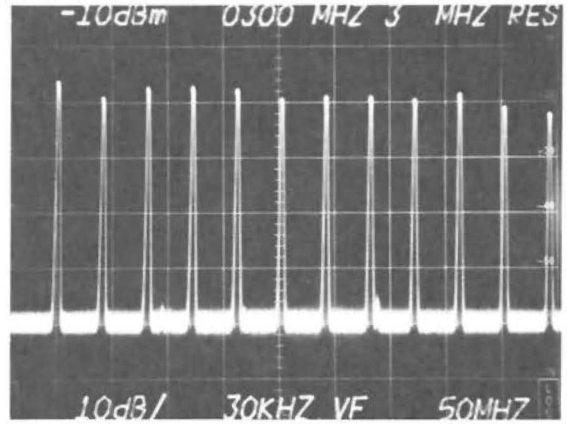


Measurement of intermodulation products was of great concern in these tests. Figure (23) shows the RF spectrum of the combined RF signals at the input to the laser transmitter. Figure (24) shows the APD output at the end of the 20.9dB test path with 12 channel loading. The second-order intermodulation product center-frequency peaks can be seen between channels, and are 30-35dB down.

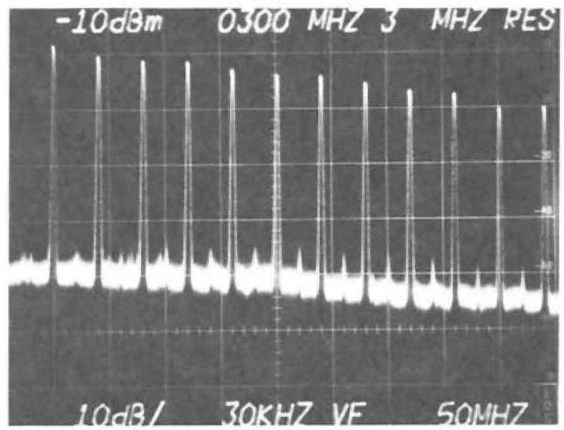
Protection ratio analysis performed by the vendor predicts that this system can tolerate, at the limit of measurable video distortion, 16MHz deviated interfering carriers which are at least 38dB down at center frequency, and at least 25dB down 20MHz from center. Figure (26) illustrates this protection ratio curve. It was prepared by measuring the beat distortion on a fixed-frequency 8MHz peak-deviated video signal, produced by an interfering signal with 16MHz peak deviation, as a function of the frequency offset of the interfering signal center-frequency. The second-order product center frequency points in Figure (24), which are offset by 20MHz and are 30-35dB down, should not produce measureable video distortion.

Figure (25) shows the system with one channel removed, so that the effect of third-order (and other odd-order) products, the center frequencies of which fall on-channel, can be observed. The sum of the odd-order products was measured to be 38-40dB down at center-frequency, and should also produce no measureable distortion. This was borne out in the video tests performed.

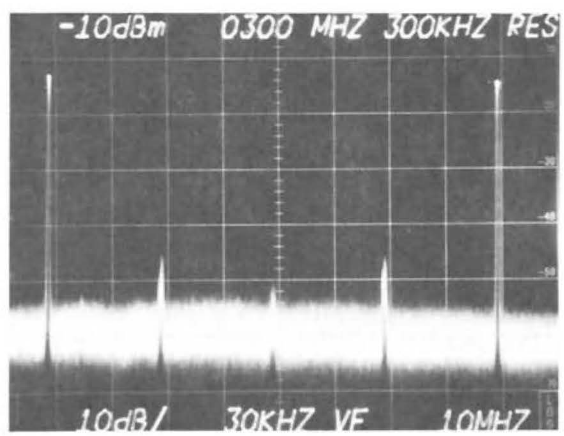
< Figure 23 >



< Figure 24 >



< Figure 25 >

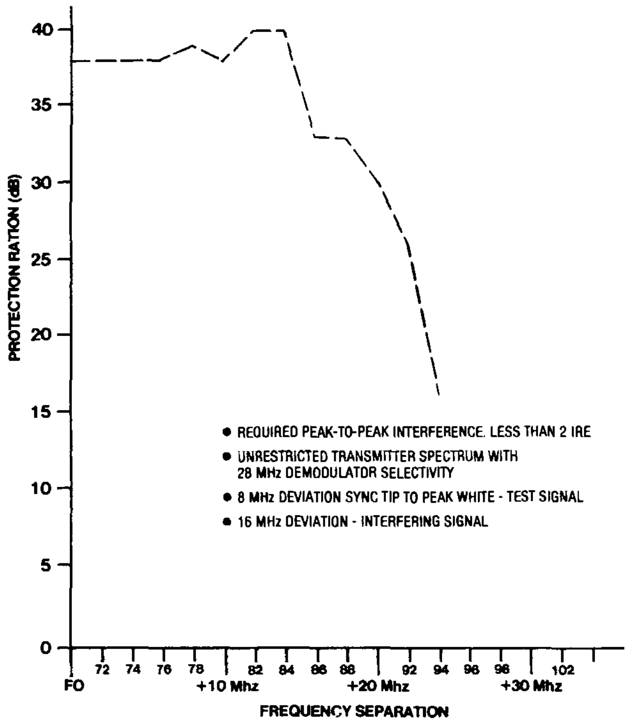


The results of the 12 channel tests leave a question as to what the ultimate limitations of this system are. One, certainly, is bandwidth. Figure (27) illustrates the frequency response characteristics of both the laser and the avalanche photo-diode. It is clear that, while it is theoretically possible to add additional channels to the system, the frequency characteristics of the optical devices will rapidly become a limitation. In addition, ultimate single-mode fiber system bandwidth is a function of the spectral purity of the laser used. This is due to the non-uniform velocity of propagation of light in the fiber as a function of frequency and the resulting dispersion effects over the distance traveled. Thus, if the laser changes frequency as it is amplitude modulated, some dispersion will result in the fiber, and an effective bandwidth limit will be established over a given fiber length. This effect was not a limiting factor in this system, despite its relatively long fiber path. It is assumed that high-purity single-mode lasers currently under development will reduce the impact of this constraint.

< Figure 26 >

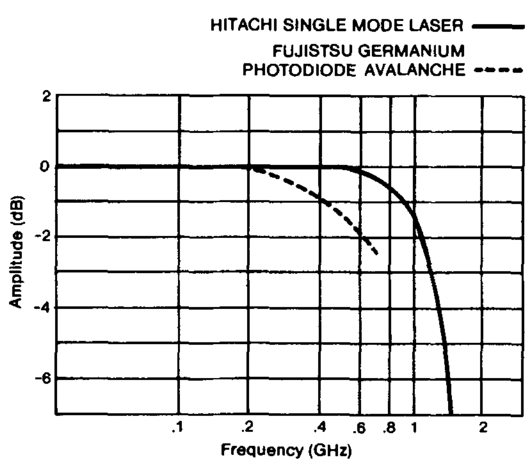
PROTECTION RATIO

CARRIER-TO-INTERFERENCE RATIO VS INTERFERING SIGNAL FREQUENCY SEPARATION



< Figure 27 >

FREQUENCY RESPONSE



In summary, the system measured in the 12 channel, 20.9dB path loss test configuration seems to provide a good balance between potential performance limitations contributed by even/odd-order intermodulation products, optical device frequency response, and noise performance. The ability to carry 12 channels 30 miles or more on a single-mode fiber with relatively inexpensive terminal equipment opens many possibilities for CATV applications. When the distances that must be traversed are not so great, the relatively large power budget available may be used for branching of the system to feed a number of hubs from a single transmission point, or for the insertion loss contributed by WDM diplex filters inserted to add additional transmission capability at 1550nm (in either the forward or reverse direction). It appears probable that the CATV industry is on the verge of rapidly accelerating use of this technology because of the convergence of performance and economics.

SYSTEM ECONOMICS

System Cost

The following are updated cost assumptions made for systems which utilize FM video on coaxial cable, and the digital and analog fiber optic transmission systems installed and tested at Oceanic Cablevision. There will, of course, be variations with each specific application.

FM, FDM ANALOG SIGNALS ON FIBER:

TERMINAL EQUIPMENT COST PER CHANNEL	$7050.00
FIBER COST:	
Single Fiber	$0.30 per/ft.
2 Fibers	$0.45 per/ft.
3 Fibers	$0.60 per/ft.
4 Fibers	$0.75 per/ft.
5 Fibers	$0.90 per/ft.
6 Fibers	$1.05 per/ft.
7 Fibers	$1.20 per/ft.
8 Fibers	$1.35 per/ft.
CHANNEL CAPACITY	12 CH/FIBER
DISTANCE BETWEEN REPEATERS	30 MILES
REPEATER COST PER CHANNEL	$6500.00

TDM, WDM DIGITAL SIGNALS OF FIBER:

(FIBER COST SAME AS ABOVE)	
EQUIPMENT COST PER CHANNEL	$13645.00
CHANNEL CAPACITY	4 CH/FIBER
DISTANCE BETWEEN REPEATERS	26 MILES
REPEATER COST PER CHANNEL	$9175.00

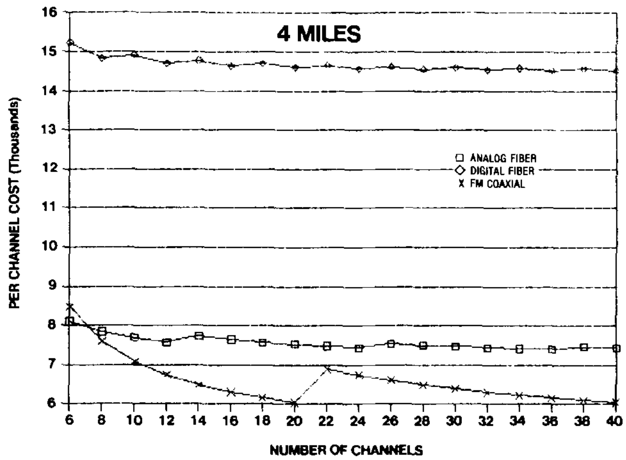
FM SIGNALS ON COAXIAL CABLE:

CABLE, AMPLIFIERS & POWER SUPPLIES	$0.66 per/ft.
PRESENT VALUE OF MAINT & POWER... (10 years, 12% annual discount rate)	$0.33 per/ft.
TERMINAL EQUIPMENT PER CHANNEL	$5000.00
CHANNEL CAPACITY PER TRUNK	20 CHANNELS

Economic Trade-Offs

The graphs in Figures (28) through (34) illustrate economic trade-offs under a variety of conditions between the three systems, based on the assumptions presented above and assuming equal labor,

< Figure 28 >



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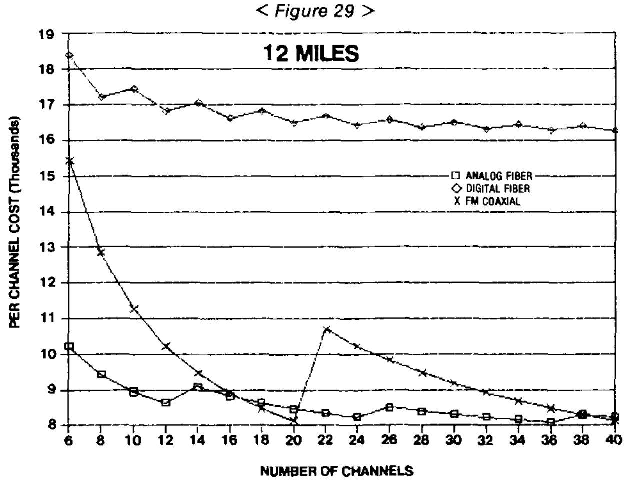
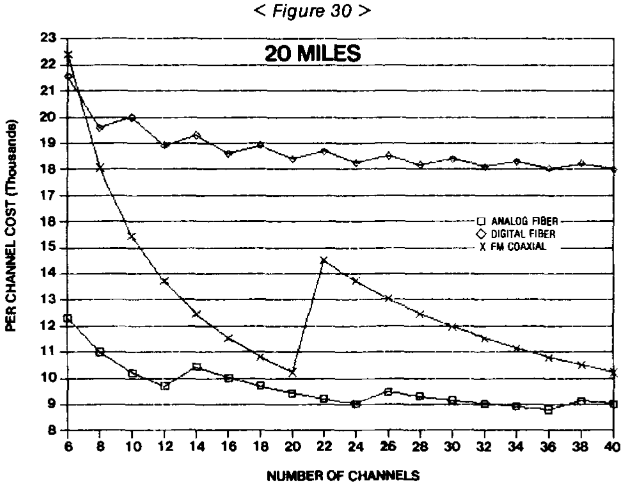
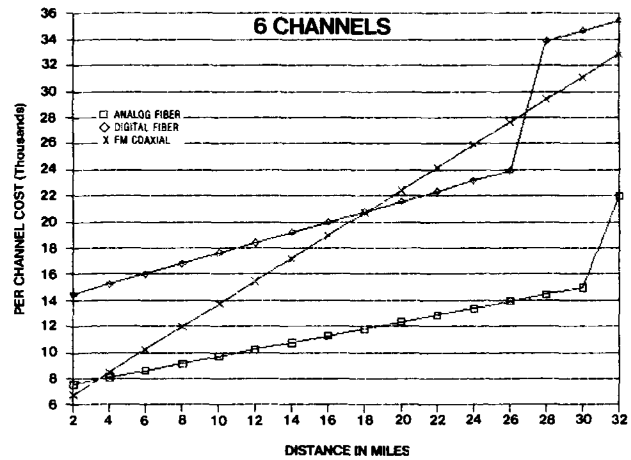


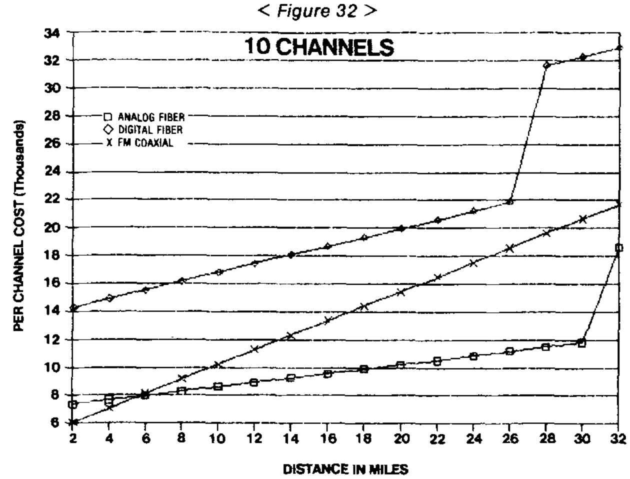
< Figure 30 >



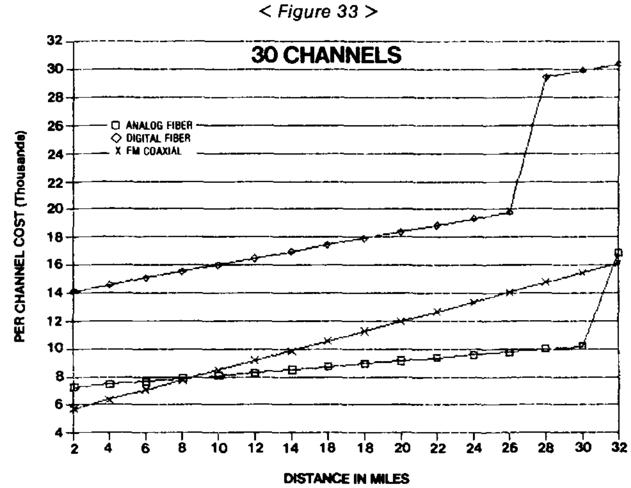
< Figure 31 >



< Figure 32 >



< Figure 33 >



duct, and strand costs for all 3 systems. Total cost per channel is plotted against a variety of distances and channel loadings. Break-points occur where a second cable is added to the coax system for additional channels, where additional fibers and lasers are added to fiber systems, and at distances where fiber repeaters are required.

It is clear that digital technology, based on the assumptions above, is attractive primarily in very long-haul applications where repeatability becomes critical. It is this technology, however, which may have the most potential for dramatic capacity increase and cost decrease in the next few years.

FM video on coaxial cable and FM, FDM video on single-mode fiber show much more closely comparable economics. While each application must be analyzed individually, it is clear that analog video transmission on fiber is often the least expensive alternative, particularly when the present value of the significantly higher ongoing operating costs of a coaxial system, with its amplifiers and power supplies, is included (as it is here).

There is an additional factor which is difficult to represent in either performance or cost comparisons between coaxial and fiber systems. That is the significantly greater reliability exhibited by fiber systems (with their smaller, tougher cable, and passive nature) over long distances. The vulnerability to amplifier, power supply, and power utility failures which are inherent in FM coaxial systems are almost entirely avoided. This factor is of greater importance as the CATV industry moves into an era of increasing competition and demand for service quality from subscribers.

CONCLUSION

The analog fiber optic system tested marks the emergence of a second generation of fiber transmission technology which is economically applicable to the CATV industry. Digital tranmission on fiber has a place today and may become a competitive alternative as digital components make advances in increasing speed and decreasing costs. Analog systems appear to be capable of performance and economics which will make them very useful for some time to come.

While FM video on coaxial cable remains a well understood, viable alternative in some applications, the number of those applications is decreasing dramatically. For point-to-point transmission of video and other CATV system signals, analog transmission via fiber is an option which simply must be considered.

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PAY-PER-VIEW: SAN ANTONIO - A SYSTEM CASE STUDY

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ABSTRACT

Two-way technology was among the first methods of implementing pay-per-view. Despite its early promise, the use of two-way technology has not become widespread and its use appears to be decreasing. After a review of some of the technical and operational issues we will describe an interactive two-way cable system that is successfully operating. A look to future services will also be made.

INTRODUCTION

Despite its early adoption and seeming promise, two-way interactive cable has not become widespread, and appears to be decreasing in terms of usage. Early interactive pay-per-view services are being disbanded, leaving only franchise determined security systems and cable operator plant communications as the primary uses. Despite the increasing number of CATV systems being built with two-way capabilities, only a very small number of active two-way plants exist.

Conventional Wisdom

The primary reasons for the apparent failure of two-way technology have been:

- The systems are not reliable.
- The operating and maintenance costs are too high.
- Subscriber terminal costs are too high.
- In real time systems peak ordering capabilities are limited.

Technology Issues

Most of the previous real-time approaches used a polling technique to interrogate the individual subscriber terminal transaction status. In its simplest embodiment, the cable headend would poll downstream in a predetermined sequence, the status of each susbcriber terminal. The subscriber terminal, upon being polled, would transmit to the headend its transactional status. If a buy had been made, the necessary data would be transmitted upstream.

If peak loads become large, polling speed and the rate of data transmission become important. As polling speed and data transmission rates increase, bandwidth requirements increase, and as bandwidths increase, noise becomes a problem. Noise arises from a variety of sources, internal and external to the cable plant. In an attempt to isolate noise generated within and without the plant, provisions for isolating sections of the cable plant can be implemented. Bridger switching is such an approach, but it primarily serves to reduce internally generated noise. Ingress, which is a point source of noise, remains a problem within the bridger switch isolated section. These approaches to high polling and data rates resulted in increased bandwidths, bridger switching and increased complexity at the headend.

Why Real-time?

Many of the problems cited could have been mitigated by the use of store-and-forward techniques instead of real-time. Slower polling and data rates, as well as simpler headend implementation could be possible if no real-time requirement was imposed. Careful analysis revealed that the trade-off would result in non-volatile data stored on-premise along with a self-authorizing subscriber terminal. It was felt that the potentially vulnerable links among the subsriber upstream transmitter, addressable converter and the return path would create potential security problems. Minimizing these security problems within the existing technologies available would result in a subscriber terminal that was not cost effective.

Economic Issues

Cost, particularly in-place cost, is an extremely important criterion in any two-way, or for that matter, in any pay-per-view system. If we examine a hypothetical pay-per-view transaction at $5.00, half of that goes back to the programming provider. That leaves $2.50, out of which must come contribution against profit, equipment amortization and overheads. Let us assume that a typical subscriber will make three $5.00 pay-per-view transactions per month and that on a per transaction basis the cable operator wants a 30% margin, or $1.50, leaving only $1.00 to contribute against equipment amortization and other cost. If one assumes $0.75 for other costs and $0.25 for subscriber terminal amortization, the cost of a telephone call, one is left with $0.75 a month to write off the in-place cost of subsriber terminal. On a seven year basis that is less than $50.00!

Design Criteria

With the previous discussion in mind, the final criteria for a two-way interactive pay-per-view system that would meet the challenge of a real-world consumer CATV application were:

- The system had to be reliable
- The system had to be secure to protect a valuable revenue stream
- The system had to be capable of operating in the CATV plant environment without the costs of earlier two-way technologies
- The technology had to be cost effective, with the subscriber transmitter terminal at less than $50
- The implementation be user-friendly and capable of true impulse pay-per-view transactions.

SYSTEM DESIGN

The first task in designing the system was to understand the dimensions of the CATV plant environment. An engineering task force was organized and spent the better part of a year traveling among cable plants. This time was spent measuring and characterizing a number of plants, and entailed hauling and setting up spectrum analyzers and other test gear throughout the country. These tests have been described previously (reference 1), and the results were that a sizeable amount of noise exists, consisting of white noise, common-mode distortion and significant amounts of ingress.

Polling versus Contention

Polling techniques, when implemented in a real-world CATV plant suffered. The compromises necessary to achieve high speed data and polling rates, bandwidth and plant isolation from noise with bridger switching were essentialy conflicting and had given rise to many of the problems that caused two-way to be written off. A fresh approach was needed, and that was provided by two departures from previous technology. The departures were in the use of contention instead of polling as the technology for the return data mechanism, and in the use of bi-phase shift keying instead of frequency shift keying as the modulation mechanism.

Access Protocol

Tree-and-branch topology is used in the majority of two-way cable plants with the downstream channel broadcasting to all the subscriber terminals at the same time from the system headend. As a consequence there is no collision or message interference since there is only one user, the headend. The upstream or return channel is a different situation; here many users are trying to reach one node, the headend, and unless some arbitration mechanism is enforced there will be message collisions and interference.

In the polling systems, the headend provides the arbitration mechanism by selectively isolating all but one susbscriber terminal at a time in an orderly time or frequency sequence. The rationale for choosing the slotted aloha contention system has been previously described (reference 2) and is based upon developments in satellite and local area networks.

This system operates in dual-modes. Contention is used to obtain fast response for a large number of users under bursty data traffic conditions. To achieve more reliable operation and higher throughput, two upstream channels are used, with the subscriber transmitter alternating between the two with a proprietary backoff algorithm. All transactions originating from the headend utilize a polling technique, in contrast with those originating from the subscribers, which use the contention technique.

Modulation

Bi-phase shift keying modulation is used for optimum performance and efficiency in the bandwidth and spectrum chosen for the upstream channels. The headend receivers use a narrow IF, matched filtering and digital correlation techniques which, along with the data format, provide high message throughput under heavy impulse noise and ingress. The resulting system is extremely robust and operates remarkably well at C/N ratios of less than 12 dB.

Headend Considerations

Since the system operates in real-time, existing approaches used in billing and system control were not suitable since many of these require seconds for an individual transaction. A new system controller was developed, along with the necessary software, to process all the elements of a transaction external to the billing computer. This includes data reception, account and authorization updating and addressable decoder authorization. These transactions, along with a subscriber file, are in active memory and do not require disc access. Upon command from the billing computer, this information is downloaded into the billing system at some convenient time post-event.

Hardware Implementation

The final subscriber hardware is extremely user-friendly and consists of an add-on two-way module that is user installed by plugging the module into an existing Z-TAC one-way addressable decoder using two cables. These cables provide power, control signals and RF loopthrough. There are no adjustments required at installation, thus the customer self-install helps eliminate a service call and to achieve the <$50 in-place cost target.

The unit has three LED indicators: WAIT (yellow), ERROR (red) and OKAY (green). When the user initiates a transaction the WAIT light is illuminated for a few seconds, after which the OKAY or ERROR light is activated. In addition, the scrambled channel, to which the subscriber is tuned, becomes unscrambled along with the illumination of the OKAY LED. Because the system was designed at a time when the industry was regulated, opinion polling was provided and is capable of of up to 99 multiple responses.

System Monitoring

For the CATV operator, two important monitoring features were provided: channel and status monitoring. In the polling mode the headend system controller can interrogate the subscrber terminals to determine to which channels they are tuned. This data is stored in macro form to provide subscriber anonymity and to avoid privacy problems. If necessary the terminals can be modified at the time of manufacture to delete this feature. Status monitoring is available in two ways. Subscriber transmitter power output is adjustable, and at the time of installation it is performed automatically by the headend system controller. The headend receiver measures power and the adjusted power output level is stored in the computer for future reference. Measurements of power and signal-to-noise are also available for plant maintenance purposes. Up to 50 two-way converters can be monitored to determine plant status and to help predict possible problems. These "canaries" are placed in strategic locations such as hubs and branch ends.

SAN ANTONIO

The Rogers' San Antonio cable system is enormous, it is one of the largest cable systems in the country. Some of the system statistics:

203,000	Subscribers
4,500	Plant miles
9	Hubs

The plant was rebuilt for two-way and Zenith Z-TAC and Z-VIEW were chosen to initiate addressability and two-way interactive services. With the introduction of new tiers in August, 1984, subscribers choosing those tiers received a Z-TAC/Z-View. Over 80% of these subscribers picked up their units at cable offices and self-installed them. Less than 20% required a technician for installation. Over 30,000 units were obtained by customers waiting in long lines in 100 degree heat because demand was underestimated. In March, 1985 the San Antonio system was officially activated as a two-way interactive system with the introduction of additional pay services, among which were a movie and sports pay-per-view service. We shall now review the results of the pay-per-view service and its impact upon existing pay services. In addition, operational impact of two-way upon the system will also be reviewed.

Pay-per-view Revenue

In Figure 1 we have plotted subscriber headcount and gross revenue since the introduction of two-way interactive services in March, 1985.

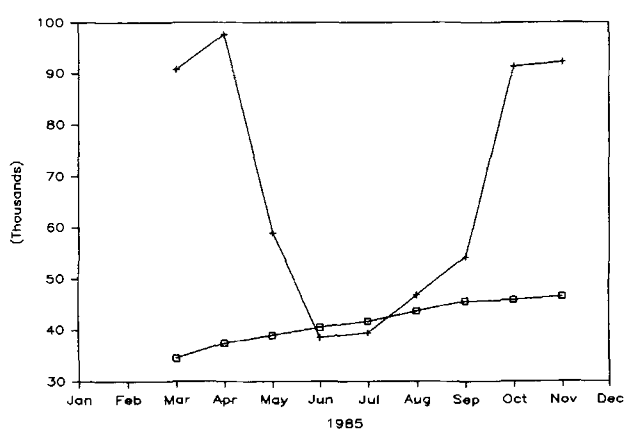

Figure 1. Gross Revenue and Subscribers for Pay-per-View

Subscriber growth is observed to be consistent and will be well over 50,000 at publication. Gross revenues show an initial peak and then drop off suddenly. The drop is attributable to the summer doldrums. From May through September, the local sports service had no offerings, and in addition the movies available for the pay-per-view service in that period gave subscribers the opportunity to seek other forms of amusement. One cannot overemphasize the necessity for strong programming choices. The increasing number of delivery vehicles for pay-per-view services should improve the situation. The availability of better movies and the return of the sports service brought the gross revenues up sharply in October, 1985. On a per Z-VIEW subscriber basis, the gross revenue curve follows a similar trend in Figure 2.

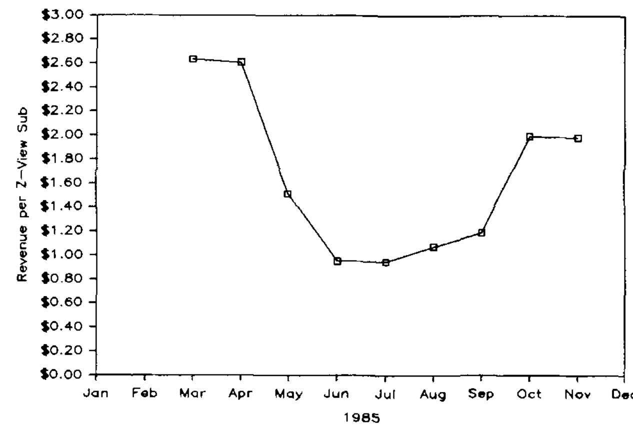

Figure 2. Gross Revenue per Subscriber for Pay-per-View

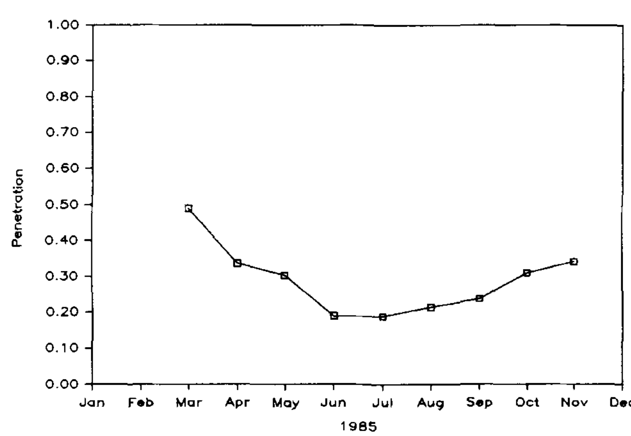

Figure 3. PPV Penetration

Figure 3 shows the effective penetration among two-way pay-per-view subscribers. It too follows a similar trend,an initial peak, declining interest with the summer doldrums, and a steady rise thereafter as the programming picks up.

Impact Upon Other Pay Services

A yet unresolved, and fear inspiring concern is the effect of pay-per-view on the existing pay services. Figure 4 shows

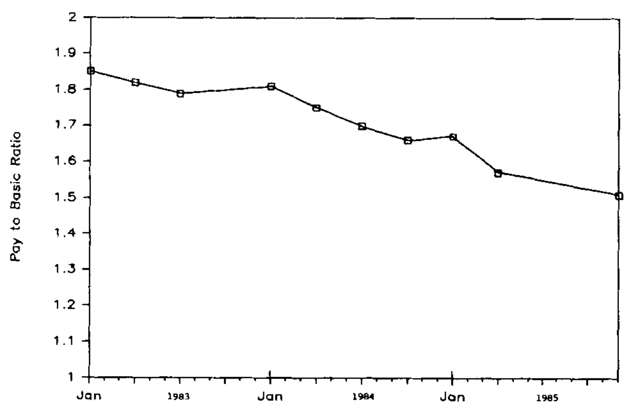

Figure 4. Pay-to-Basic Ratio for 1983, 1984 and 1985

the pay-to-basic ratio over a period of three years, with a period prior to pay-per-view. The trend is down, which mirrors system behavior elsewhere, with perturbations about the trendline explained by increases in subscriber rates in early and late 1984. The last increase in rates was also coupled with the imposition of a sales tax on cable fees. From the available evidence, limited as it is, there seems to be no strong causal impact upon existing pay services.

Subscriber Growth

Subscriber population has remained stable near the 200,000 level, having dipped below 200,000 at the time of rate and tax increases, and gradually climbing back to sligthly over 200,000.

Operational Impact

One of the most significant trends has been the positive impact upon system operation and reliability. The total number of technical staff has dropped from 369 to 250 from September, 1984 to September, 1985. The magnitude of the drop is muted by the fact that many of the district office functions have been added to that of the technical staff, thereby masking the actual decrease in technical staff needed. A significant corollary to this is the sharp drop in service calls, which have dropped 50% in the same period. A good part of this can be attributed to the status monitoring capability and the ability to see potential problems developing. The trend continues and has not leveled off yet.

A LOOK TO THE FUTURE

The number of pay-per-view channels is being increased from one to two. There will be a separate movie channel, along with a channel for sports and special events. The new delivery and pay-per-view offerings will provide additional service to subscribers and an increase in revenue potential. Opinion polling is being used in a variety of ways, some conventional and some unconventional. There is a weekly local talk show where subscribers are encouraged to register their opinions. Response is in the several hundreds. More interesting yet is the use of the two-way capability to allow subscribers to upgrade to a new service, such as the sports channel, for a month on a trial basis. A local network affiliate leases one of the cable channels and provides programming distinct from its over-the-air fare. They will be introducing an opinion polling movie choice. Viewers may select one of two movies, just prior to showing, by voting via opinion polling.

References

1) "Two-Way Cable Plant Characteristics"; R. Citta, D. Mutzabaugh; Zenith Electronics Corporation; NCTA Technical Papers, June 1984.

2) "Is Two-Way Cable Dead"; V. Brugliera, R. Citta, et al; Zenith Electronics Corporation; Communications Engineering & Design; September, 1985.

QUANTIFYING RFI ISOLATION

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ABSTRACT

The cable TV industry is struggling through the process of securing their systems from radio frequency interference. (RFI) Most important is complying with the new FCC rulings. Radiation from the cable television system is a problem which must be dealt with to protect ourselves from the liability which could occur should excessive radiation be found by the FCC field audits.

There are several systems in operation today that purchased equipment (mostly passive products) which did not contain wire meshed-type gaskets for the purpose of improving the RFI shielding characteristics. Recent testing has shown that some systems may measure egress from their system above the FCC limits and the signal leak has been traced back to units not having RFI gaskets. Several devices were tested including trunk, line extenders, splitters, directional couplers, and taps. Several manufacturer's were quantified both with RFI gaskets and without. Testing was performed at the approved FCC site located at Magnavox's facilities in Knoxville, Tennessee.

The scope of this discussion is to address the electronic equipment and not other factors such as quality of installation, connectors, and cable quality. This paper will explain the physical testing facilities, test equipment setup and procedure, results of testing, and suggest some solution to potential problems.

INTRODUCTION

Is an RFI gasket necessary for CATV components to meet the FCC limits on RFI? The answer to this question is a qualified <u>YES</u>. In some systems, RFI limits can be achieved with or without an RFI gasket, but others most definitely do require these gaskets on trunk amplifiers, line extender amplifiers, splitters, directional couplers, and taps; or any other devices having high RF level input and outputs.

A wire-mesh gasket has been proven to be effective in improving RFI from products. Normally there are two types of gaskets used on any individual CATV product. One being the wire-mesh gasket, and the other a weather-sealing gasket. Experiments have been performed using integrated wire-mesh and weather-sealed gaskets. This combination has proven to be sufficiently effective on amplifiers; however, the best performance on passive products has been separate wire-mesh and weather-sealed gaskets. At Magnavox there has also been testing done with metal impregnated neopryne and conductive type weather-sealed gaskets. Neither of these two combinations have proven to be as effective as the wire-mesh gasket.

It is beneficial to be able to calculate expected RFI performance from a CATV device. Towards this end, the testing was performed to determine a corrolation between the input level and radiated output level. This would be specified in terms of RF isolation. It is also desirable to know the amount of RF isolation necessary to meet the limit set by the FCC.

As the input level to a CATV device increases or decreases, does the radiated energy increase or decrease on a consistent basis? The testing performed and the results obtained indicate a reasonable level of consistency. If the input and output levels of the devices used in a CATV system is known, as well as the RF isolation the device provides, one can theoretically calculate a level of RF radiation; or at least determine if there is sufficient head room to assure FCC compliance.

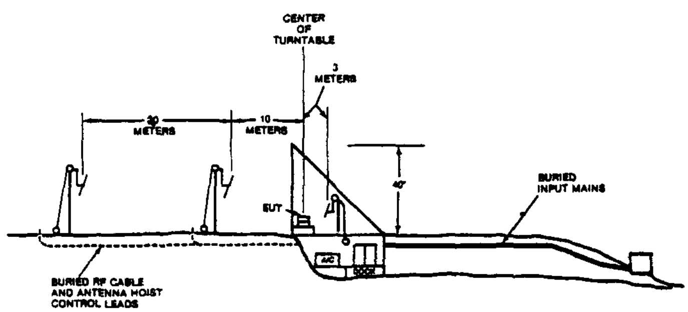
The information presented here will not allow an accurate prediction of radiated RFI energy; however, it does provide a way to determine the probability of complying or not complying with the FCC. There is conclusive evidence that some systems will have problems with passive devices not having RFI gaskets. This evidence also indicates that radiation of RF signals will take place on amplifier housings that are opened for service. The higher the input or output level, the higher the level of radiated energy. Therefore, a passive that is located closer to the output of an amplifier will tend to have a higher chance of radiation than a passive located at the end of the feeder line. Thus, when trouble shooting CATV systems for offending devices, one should look at the begininning of the feeder lines or the output of line extenders. Any system not having RFI gaskets, should retrofit the devices closest to high level bridger and line extender outputs. As a safety factor, RFI gaskets should be retrofitted in all passives and taps in a CATV system.

Suppliers of CATV devices provided an optional selection of components for the CATV operator to choose. RFI gaskets were a more expensive option on passive items, and sometimes not selected. Lower bandwidth system or systems operating with moderate feeder levels could meet FCC requirements without wire-mesh gaskets. Tap port terminators and proper base plate torque is critical in minimizing leakage. Indoor passives of the type typically manufactured offshore were major sources of egress and ingress, though major improvements have been made by some suppliers.

Test Site

Magnavox used its FCC registered test site for RFI testing. -1- It is located on the grounds of our sister company, located in Knoxville, Tennessee. The facility was designed to meet FCC Part 15 standards with future EMI Legislation in mind. Many hours of research have proven this facility to meet regulatory requirements. It houses an all-weather three meter test site, a two meter tem cell, and a conducted line radiation measurement area. The site can also be used for 10 and 30 meter testing. Reference Number 1 describes specific detail for the design of this site.

The three meter site was used for the RFI testing. Illustration Number one shows a cross view of the three 10 and 30 meter sites. Note that the three meter site is completely enclosed in a triangular building. Both the device under test (DUT) and the receving antenna are located within a triangular building. The 10 and 30 meter sites have their receiving antennas located outside of the buildings, and the device under test remains inside the building. The antenna polarization and elevation (height above the ground) are all controlled remotely from the instrumentation test area.



3 Meter Enclosed Site with 10 or 30 Meter Capabilities

ILLUSTRATION # 1

Illustration Number 2 shows the location of the measurement instrumentation. Note that all instrumentation is located below an 8 by 11 meter metal ground plane, which covers the entire three meter site. The device under test is located on a table located three meters away from a horizontally polarized antenna. The feed line for the device under test is routed from the ceiling and dropped down to the device under test such that the cable located within the test area was in the vertical plane. It was felt that this would minimize any radiation from the cable sheath. The cable length was calibrated such that the level into the device under test was known. At the receiving end a Singer Model DM105 Antenna and Balun fed a length of coaxial cable which was routed into the vertical plane down through the floor ground plane, then routed to a spectrum analyzer (HP Model 8568A). Measurements from the analyzer were calibrated to take into consideration the antenna factor and the loss in the cable. The measurement absolute level in dBmV was then taken from the analyzer.

The scope of this discussion defines RFI isolation as the difference between the dBmV measurement on the analyzer, and the highest level within the device under test. For example:

A = Amplifier Output Level (dBmV)
M = Measured Level (dBmV)
I = Isolations (dB)

1. If an amplifier has a 10 dBmV input level and a 40 dBmV output level with an analyzer measurement of -60 dBmV, the RFI isolation is defined as:

$$A_O \quad - \quad M \qquad I$$

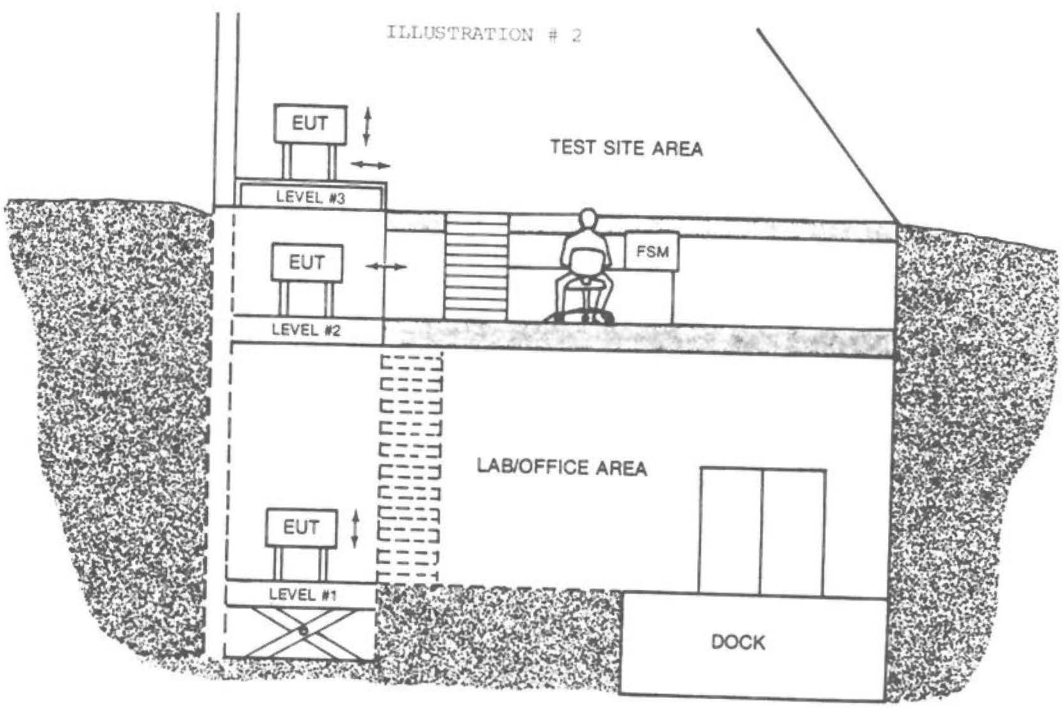
$$40 \quad - \quad (-60) \quad = \quad 100 \text{ dB}$$

If the DUT is an amplifier, the highest output level is used in the calculation.

2. If the device under test is a passive device with an input of 45 dBmV and the measurement on the analyzer was -45 dBmV, the isolation is calculated as:

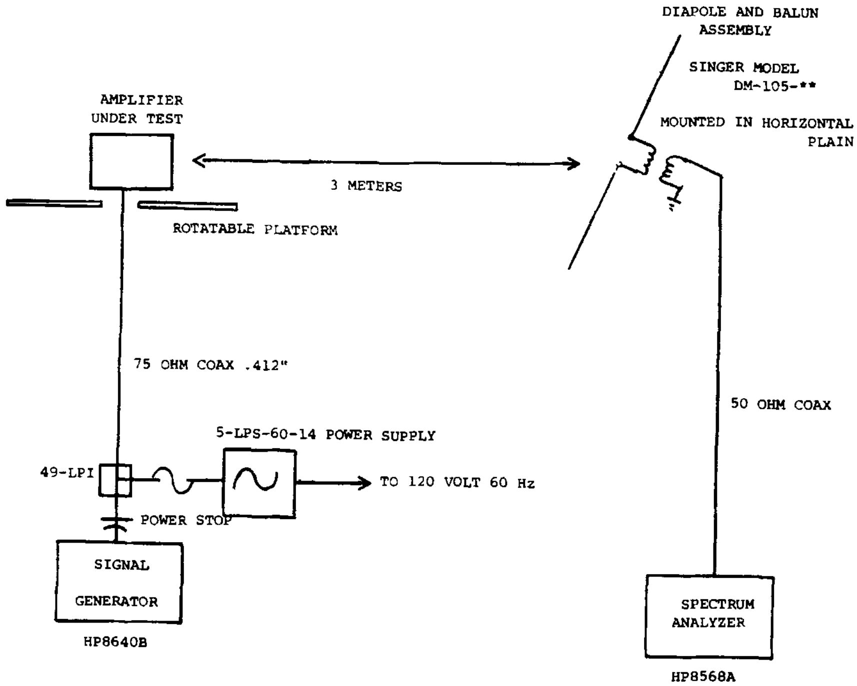
$$P_I \quad - \quad M \quad = \quad I$$

$$45 \quad - \quad (-45) \quad = \quad 85 \text{ dB}$$



3 Level Hyd-Hoist and FSM Receiving Area

ILLUSTRATION # 3



If the device is a passive product, the input level is used in the calculation of isolation.

Testing started using the test setup as in Illustration Number 3. Inconsistencies were noted, and it was determined that the spectrum analyzer noise floor was causing errors in the measurements. A low noise amplifier was added to the output of the Singer Model DM-105 antenna. This provided the dynamic range necessary for consistency. Some of the data presented was based on testing prior to the insertion of the preamplifier. The subsequent discussion on taps and the noise floor of the test set was considered in the conclusions.[1] The device under test was placed on a table which could be rotated by 360 degrees. A maximum reading on this spectrum analyzer was then recorded.

Taps

Samples of taps from 5 different vendors were tested. Magnavox taps were tested with and without wire-mesh RFI gaskets. Other manufacturers taps did not include RFI gaskets. The taps were placed on the test table with the baseplated and subscriber ports facing the antenna. All tap ports were terminated and signal was applied. The purpose of this test was to determine if any specific supplier could perform to FCC specifications without RFI gaskets. Depending on the input levels to the devices, FCC specifications could not be met by any supplier not incorporating an RFI gasket. With RFI gaskets, RFI specifications were met at the typical operating levels of 53 dBmV and even higher. To illustrate an improvement in isolation with the RFI gasket, data was taken on taps with and without RFI gaskets. Figure Number 1 illustrates samples of this data. In columns 4 and 5, RFI isolation is shown for taps containing a wire-mesh gasket. In columns 6 and 7, isolation is shown without the RFI gasket. On the average, a wire-mesh gasket improves isolation by approximately 10 dB. Typically, at the lower frequencies, there is little improvement shown with the wire-mesh gasket. At higher frequencies, there is as much as 20dB improvement in RF isolation.

FIGURE #1 ISOLATION IMPROVEMENT WITH WIRE GASKET

1	2	3	4	5	6	7
	(DBmV)			(DB) Isolation		
Freq	Input to DUT	49tfc	4920/4m	4908/2m	4911/2	4900/2
30	66	103.6	109.4	110.6	107.7	108.7
54	66	104.6	105.6	105.5	109.1	108.8
125	65	80.4	99.3	100.2	91.9	95.2
135	65	77.6	100.4	99.9	92.5	91.3
185	65	70.1	101.5	100.8	83.8	85
200	65	68.3	95.9	96.5	82.1	83.9
216	65	67.5	92.2	93.3	80	81.7
330	65	67.3	94.7	96	76.8	78.4
450	58	54.9	91.1	88.4	70.9	72.2
AVERAGE	ISOLATION	77.14	98.90	99.02	88.31	89.47

note:--- The "m" in the model number indicates a wire mesh RFI gasket was installed. If "m" is not indicated tes was done without RFI gasket.

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Quantifying RFI Isolation

FIGURE # 1

In order to calculate an expected level of radiation, it is important to verify that radiation decreased as level decreased. It was expected that for every dB in input level reduction, there would be a corresponding dB reduction in output radiation. From Figure Number 2, this conclusion can be drawn. Column Number 3 shows the absolute level measured on the analyzer with an input as shown in column 2. Column 4, 5, and 6 are measurements taken with the input levels reduced by 2, 6 and 8dB respectively. Each of the columns were averaged for measured signal level, and the difference between columns 4, 5, and 6 with reference to Column 3 was taken. For a 2dB reduction in input signal level, the radiated signal level reduced by 1.58dB, 6dB by 5.26dB and 8dB by 6.82dB. One would expect for a 2dB input level reduction that the output would drop by 2dB. The actual average data does not show this; however there seems to be a logical reason why this occurs. When the absolute level was measured on the analyzer, it was close to the noise floor. The noise floor added to the actual radiated signal level and caused an error. As the levels got closer and closer to the noise floor, the errors also increased. For example, reducing the input level by 2dB yielded an error of:

2 - 1.58 dB =.42 dB error

This is calculated from the difference in column four and a reduction of 2dB in input level. The error was greater in column 6 and the actual measured radiation was much closer to the noise floor. The error for an 8dB reduction is 1.18dB. This figure comes from taking the 8dB reduction in column 6 minus the difference in column 6. Column 7 in figure 2 indicates the noise floor of the test system. You can see that there is only two to three dB difference between the noise floor and the actual measurement. To confirm this logic, an exercise was performed. Refer to illustration number 4, which is a graph for correcting a spectrum analyzer measurement when the thermal noise floor is less than 16dB from the measured value. For example, refer to figure number 2. In column 4 the measured radiation level at 54 MHz is -40.9dBmV. The noise floor was -47dBmV. The difference between the noise floor and the measurement is 6.1dB. The correction factor corresponding to 6.1 from the chart in illustration number 4, is 1.2. Therefore, the correction yields a measured RFI level of -42.1dBmV. Additionally, looking at column 6 with a level measured at 54MHz, shows a -44.7dBmV (which is 2.3dB away from the noise floor). The correction factor for 2.3dBmV is approximately 3.6dB, and therefore the measured level was corrected to -48.3dBmV. Take note that there is a 6dB differential in input levels between columns 4 and 6. Subtracting the two corrected measurements:

48.3 - 42.1 = 6.2 dB difference

The expected difference in level would be 6dBmV and this illustration showed 6.2. Clearly this is within measurement accuracy.

The information obtained from our testing brings us to the conclusion that as input level to the device decreases, the output radiated level will decrease by the same amount.

FIGURE #2 INPUT LEVEL vs. RFI OUTPUT

1 FREQ	2 INPUT LEVEL (DBmV)	3 RF LEVEL MEAS'ed	4 RF @ Input -2DB	5 RF @ Input -6DB	6 RF @ Input -8DB	7 NOISE FLOOR
54	69	-39.3	-40.9	-43.1	-44.7	>-47
125	67	-35.8	-36	-40.6	-43.8	>-46
135	67	-31.4	-32.1	-36.2	-37.2	>-40
185	67	-22.8	-24.5	-28.1	-29.1	>-32
200	66	-23.9	-26.6	-29.7	-30.2	>-33
216	65	-24.7	-25.5	-30.1	-31.9	>-34
330	64	-19.5	-23	-25.9	-28.1	>-31
450	62	-11.8	-13.3	-17.6	-18.8	>-21
AVERAGE LEVEL ===		-26.15	-27.7375	-31.4125	-32.975	
DIFFERENCE REF column 3 ==			1.5875	5.2625	6.825	

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Quantifying RFI Isolation

FIGURE # 2

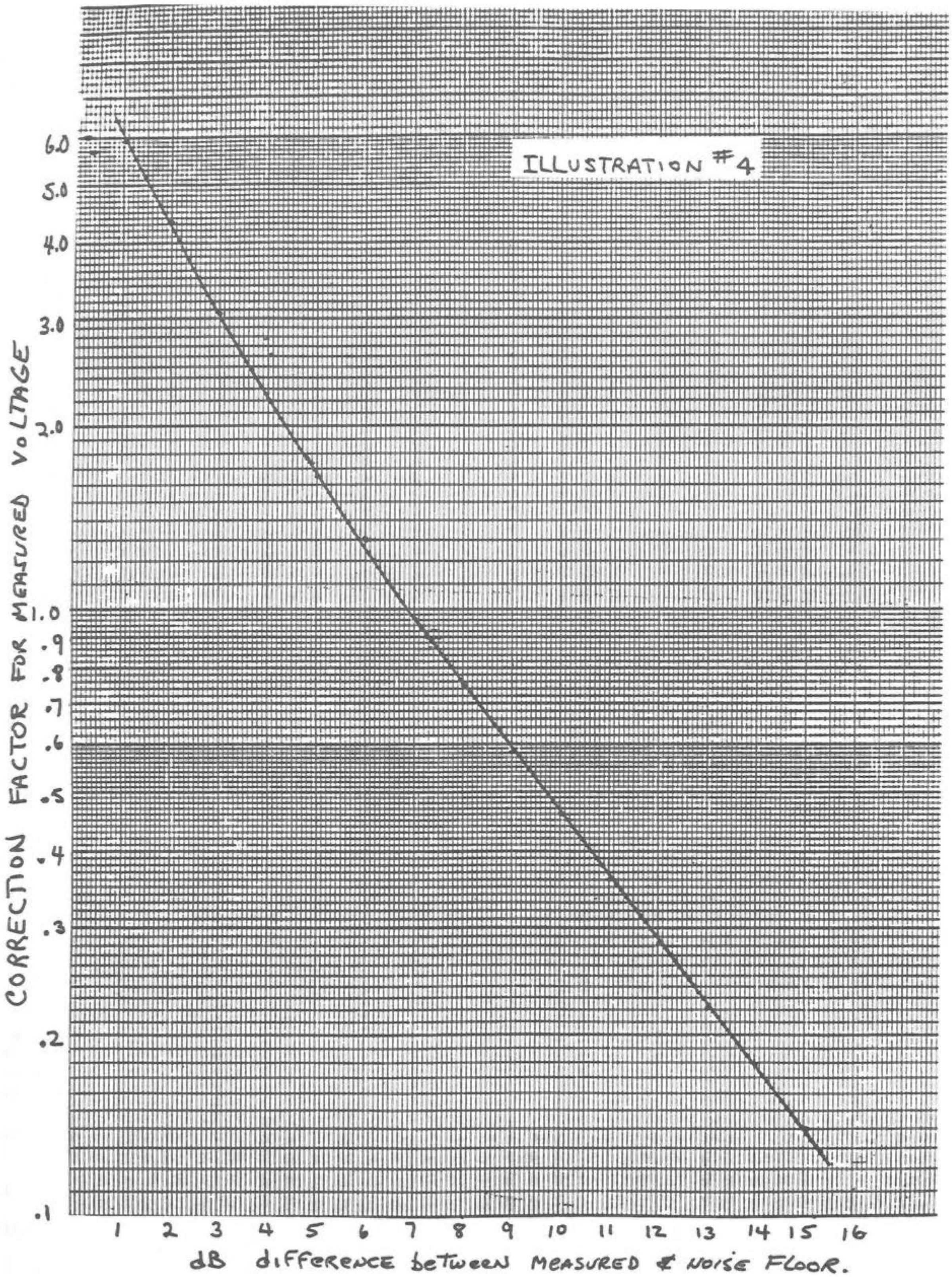
ILLUSTRATION #4
CORRECTION FACTOR FOR MEASURED VOLTAGE
6.0
5.0
4.0
3.0
2.0
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
dB difference between measured & noise floor.

There is no <u>one</u> supplier who can assure RFI isolation without wire-mesh gaskets. Suppliers using the RFI gasket typically have better performance records than those not using RFI gaskets; however, there are instances when the performance is much worse. Figure number 3 shows the isolation testing where products did not have RFI gaskets. As indicated by the boxed numbers, no one manufacturer could meet FCC specifications at <u>all</u> test frequencies.

Figure #3 Various Suppliers Products without RFI gaskets.

Tap Input Level = 53 dBmV

(DB) ISOLATION

FREQ	SUPPLIER a	SUPPLIER b	SUPPLIER c	SUPPLIER d	SUPPLIER e
54	98.5	97	93	92.4	99
125	93.5	98	90.2	86.1	93.1
135	90.9	93.8	88	86.2	88.7
185	86.1	97.7	79	98	98
200	88	88.7	78.5	98	98
216	86.9	86	78.2	98	98
330	84.3	82.8	77.9	98	98
450	73.7	72.1	67.5	77.2	81.5
AVERAGE	87.7375	89.5125	81.5375	91.7375	94.2875

note --- FCC Specifications could not be met without Wire RFI gasket as indicated by boxed numbers

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Quantifying RFI Isolation

FIGURE # 3

Typically, a measured RF isolation of 90dBmV at frequencies between 54 and 216 MHz, will be sufficient to meet RFI requirements, provided that the highest levels at the input or output of a device do not exceed 50dBmV. For example, if a tap utilizing an RFI gasket exhibited a 90dB RF isolation, it would be expected to provide sufficient isolation and meet FCC requirements. However, if a tap without an RFI gasket was installed with a level of 50dBmV, it would be expected to radiate above the FCC requirements. High levels would be present at the output of feeder amplifiers. As the signal progresses through a tap feeder line, the signal level would be attenuated through the cable and through the passives. Since there is typically 10dB less RF isolation without a wire gasket, the level in the feeder line would have to be attenuated to 40dBmV in order to meet FCC requirements. Therefore, the section of feeder from the output of a high level amplifier through the point in the feeder line where the level was attenuated to 40dBmV would require the installation or retrofitting of RFI gaskets. The probability of an RF egress above FCC limits beyond 40dBmV is low.

<u>Splitters and Couplers</u>

Measurements were made on splitters and couplers, and it was found that they generally had a higher level of RF leakage without RFI gaskets. The installation of RFI gaskets provided a greater improvement than for taps. When an RFI gasket was installed, its isolation performance was comparable to a tap with an RFI gasket. Further study must be done to discover the reasons for these results. A hypothesis is that splitters and couplers are generally enclosed in larger housings. The perimeter around which RF sealing takes place is larger, and therefore provides a higher probability of an imperfect seal, resulting in a higher RFI. The wire-mesh gasket tends to seal this larger perimeter efficiently.

There is not as much data available on splitters and couplers so as to determine an average level of RFI improvement to be expected with a gasket. Therefore, projected limits of operating levels cannot be concluded. Further study will be performed on splitters and couplers.

<u>Trunk and Line Extenders</u>

Testing was also performed on trunk and line extender amplifiers operating with levels as high as 53dBmV. As a standard feature on most CATV amplifiers, a wire-mesh gasket is installed. To the writer's knowledge, most of the installed amplifiers have RFI gaskets. No detectable RFI levels were measured from a Magnavox amplifier with housing sealed and torqued to specification. However, when the amplifier lid was opened as is necessary when an amplifier is being serviced in the field, the level of RFI radiation far exceeded FCC limits.

To the writer's knowledge, there is no CATV trunk or line extender amplifier that does not incorporate a wire-mesh or other variation of an RFI gasket. Testing was performed on Magnavox trunk and line extender amplifier products only. Therefore, a conclusion cannot be drawn for other manufacturer's.

SUMMARY

This paper presented some conclusions based on RFI testing in an FCC approved site. It is by no means a conclusive and exhaustive study. It does, however, provide some insight and suggests minimum level of RFI Isolation. A 90dB minimum RF isolation is required. Taps without RFI gaskets have less than 90dB of RF isolation. In certain instances, taps without RFI gaskets are sufficient to meet FCC specifications. Generally, it can be stated that isolations less than 70dB can be expected from taps not having RFI gaskets. It is important to adhere to manufacturer's specifications on screw and bolt torque. An overtorqued baseplate could cause warpage and result in high levels of RF radiation. Likewise, terminators should be properly torqued on F ports. A loose F port terminator has the potential to radiate at higher levels than a completely unterminated port.

Trunk and line extender amplifiers, when sealed in compliance with manufacturer's specifications should exhibit good RFI performance, and sufficiently achieve FCC limits.

Further testing and study will be performed and hopefully provide more conclusive data.

Systems having installed products without RFI gaskets can retrofit RFI gaskets to improve performance. For example, Magnavox CATV stocks gaskets which can be ordered as replacement parts. A tool has been designed to enable in-the-field installation of these RFI gaskets. For more information contact MAGNAVOX CATV SYSTEMS, INC.

FOOTNOTES

1. Fred Fisher, "Construction of EMI Test Chamber," NAP Consumer Electronics Corporation.

2. Ken Simons, Technical Handbook for CATV Systems, Third Edition, Jerrold Electronics Corporation, Philadelphia, Pennsylvania, 1968.

REMOTE CONTROL - PROBLEMS AND OPPORTUNITIES

JAMES D. SULLIVAN

MIDWEST CABLE & SATELLITE, INC.

ABSTRACT

The problems and opportunities of remote control are well documented by anyone who has wandered into the labyrinth of options and costs involved in even the most simple applications. Attempting to monitor, compile and display information from multiple monitoring points increases the complexities and costs exponentially. But, as active electronics increase, the costs of maintenance, potential failure and lost revenue also increase. As a function of limited personnel, and unsatisfied customers, we attempted to design a remote control and monitoring system. We have used the most available computers today, the IBM PC and PC Jr., and our data acquisition by "off the shelf" manufacturers. The software was mostly custom written using compiled basica and assembler as building blocks.

INTRODUCTION

As state of the art, a term whose meaning changes daily, is employed to everyday tasks there are natural concerns to the limited use cycle of the equipment. In remote monitoring very little has changed over the last several decades in basic design. While we expand our reach through use of impulse pay, a form of remote control, microwave interconnects, additional channels and deeper truck cascades, our methods of seeking the source of problems has mostly been limited to customer service complaints. Traditionally, remote control has been limited to relays and lightbulbs leaving the operators to interpret potential problems and design corrective action.

We have taken remote control into a second phase by putting to use the "intelligence" of a user programmed microprocessor.

The microprocessor is the brains of the remote monitor, with traditional relays being the nervous system collecting information for interpretation by the computer.

In the following pages, I will discuss the problems and opportunities we encountered in trying to assemble the brain and nervous system of a remote control and monitor. The complications we encountered were multiplied by the needs we had to access information from many geographically separated locations. Our application required 24 hour surveillance of electronic receivers and transmitters spread throughout the Minneapolis/St. Paul metropolitan area

In addition we had to be aware of the ongoing operating overhead of any system employed. With the apparent need to move information between the control center and the remote sites we were concerned about running up exorbitant phone line costs. In our system we did not have duplex communications available, as you might over coaxial cable. Solutions had to be found to this problem or project feasibility would be in jeopardy.

Lastly, the use of "off the shelf" hardware was of paramount concern. We had limited component production capability, as well as little spare technician time to spearhead a totally customized monitoring system. Unfortunately, the obvious choice of buying a prefabricated remote control proved too costly for the desired features, and totally inflexible to our unique needs. The result is a highbred of IBM microprocessors, Electromation Inc., interface hardware and joint custom software by ourselves and CAT Systems Inc., of New York.

The resultant system has proven to be a flexible microprocessor based remote control driven by user modified software. In the succeeding pages I will describe the techniques of operation as well as the important technical specifications used in completion of the final product.

NEEDS ASSESSMENT

Our need for remote control is brought about by the use of microwave to relay television signals from our operations center to cable television headends within a 30 mile radius. Point to point microwave communications was chosen because of its cost efficiency in sending television signals over extended distances at a minimal cost, and relatively high reliability. As we added additional paths to our microwave relay system the problem of geographic diversity became more apparent. If a tech was dispatched to a southern site for routine maintenance, it could take as long as two hours to drive to a northern site for an emergency repair. As complete failures are fairly far apart, it is impossible to convince management to add additional technicians for the occasional failures.

We found that failures were usually prefaced by deterioration of a certain component. Left unmonitored, this deterioration would not be found out until a failure had occurred. After a failure, locating the source of the problem usually ended in a response of "there's no picture". This type of assistance is worth little, except to cause panic to the service technician.

Another concern, was the cable operators who receive local commercial advertising via our microwave system. Not all operators have chosen to take our complete network feed, opting instead to switch from their local T.V.R.O. to the microwave feed only during local commercial avails. This added dimension creates a whole new set of problems relating to the inherently unreliable cue tones decoding from the satellite.

It seemed fairly straight forward that we needed an automatic method by which we could measure the performace of the interconnect. First we took a careful look at what was available from traditional remote control vendors. We found little bits and pieces that applied to our problems, but no clear solutions jumped out at us. It looked like we would just keep going along with our one tech running about putting out fires.

MICROPROCESSOR TECHNOLOGY

With the falling cost of microcomputers and the availability of prepackaged software a solution to our monitoring seemed near at hand.

First we set a listing of functions that were deemed essential to the project.

°Cost effective
°User-friendly
°Minimize use of phone lines
°Display information with easy to read graphics.
°Provide hard copy log of out of spec operations.
°Save data for reliability and outage forecasting.
°Verify the switch positions at each headend.
°Verify all voltages and alarms on receiver at each headend.
°Verify all voltages and alarms on transmitters.
°Monitor security, fire/smoke alarms and air temperature at transmitter building.

With this basic outline several of us sat down to decide which areas would get developed internally and which by outside vendors. Our initial plan called for a Commodore VIC 20 micro. Using the game part as I/O inputs we felt that a modest system could be built. After buying one unit and playing with the available software it was decided to go to an IBM PC Jr. micro for increased performance and additional flexibility. The most important of which was the floppy disk drive which made blowing PROMS unnecessary.

Once we started trying available software i.e. PC TALK, LOTUS, and PROKEY we found that it was going to take a more custom software package to give us the features we had identified. We called Joe Soll at CAT Systems, Inc. in New York, who has had considerable experience with custom software applications in remote control. We got together and came up with the following ideas for the software.

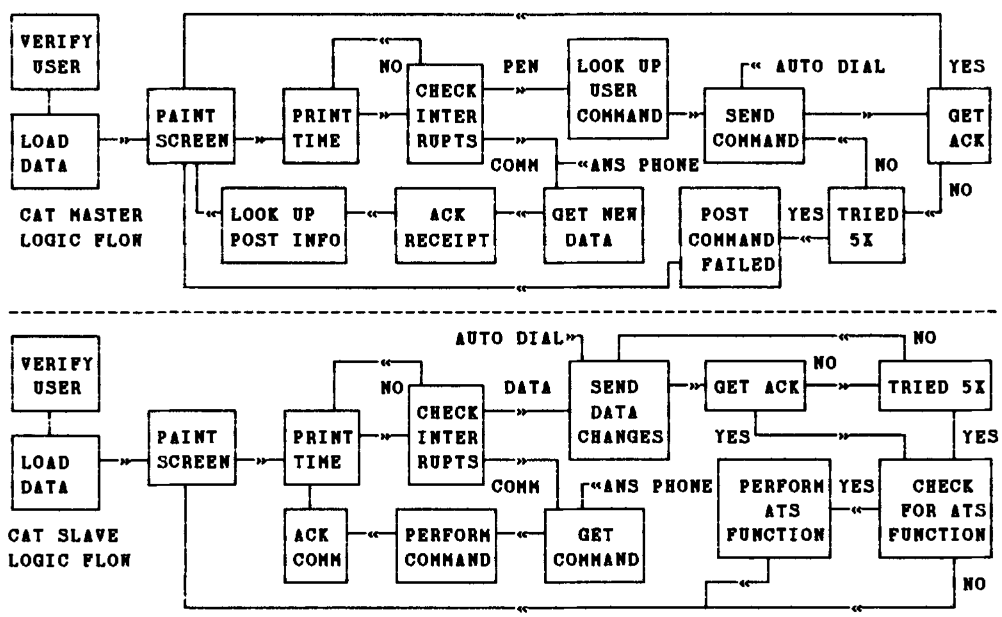
°Compiled BASICA should be used for speed in programming and versatility in making changes.
°Assembly language would be used for all I/O functions, i.e. communication, screen drawing, and light pen control.

As we went through possible configurations, it became clear that the software could be broken down into blocks. This method allowed us to see more clearly the relations between different functions that we wanted to perform. The peripheral or auxiliary programs to the main program were fairly self explanatory. Their relation to each other is best described by the following block diagram.

Communications Protocol

Communications Protocol was identified as one of our most important programs. The error free movement of information between remote site and control site is essential to basic reliability. We were unable to find "off the shelf" programs that combined the speed and accuracy features we needed. Joe worked up a protocol for us that gave us the features we required. The communication program runs in assembly language. This allows the program to run in the background. A baud rate of 1200 was selected as the optimal compromise between speed, modem cost and phone line compatibility. As we established duplex capabilities on the interconnect, a second modem will be added at the remote site operating at 9600 baud with the 1200 as a standby in case of path fade or radio failure. Naturally, data errors were a big concern as phone line quality varies from connection to connection. Joe was able to devise an error checking scheme that does not appear to slow the system down. Errors appearing at the control center have been nonexistant to date.

Another major concern for any phone line access computer is security. With the explosion of "hackers", (we've all heard the horror stories) security questions had to be resolved. Our solution came by way of using a binary protocol running on asynchronous modems. By using binary codes instead of ASKI words, there is never a prompt on a screen. In fact, when the computer picks up an incoming call it waits for a 50 digit number that it must receive before any transmission is sent. This method appears to be hack proof. Additionally, the system goes off line after 3 unsuccessful attempts to enter the code sequence.

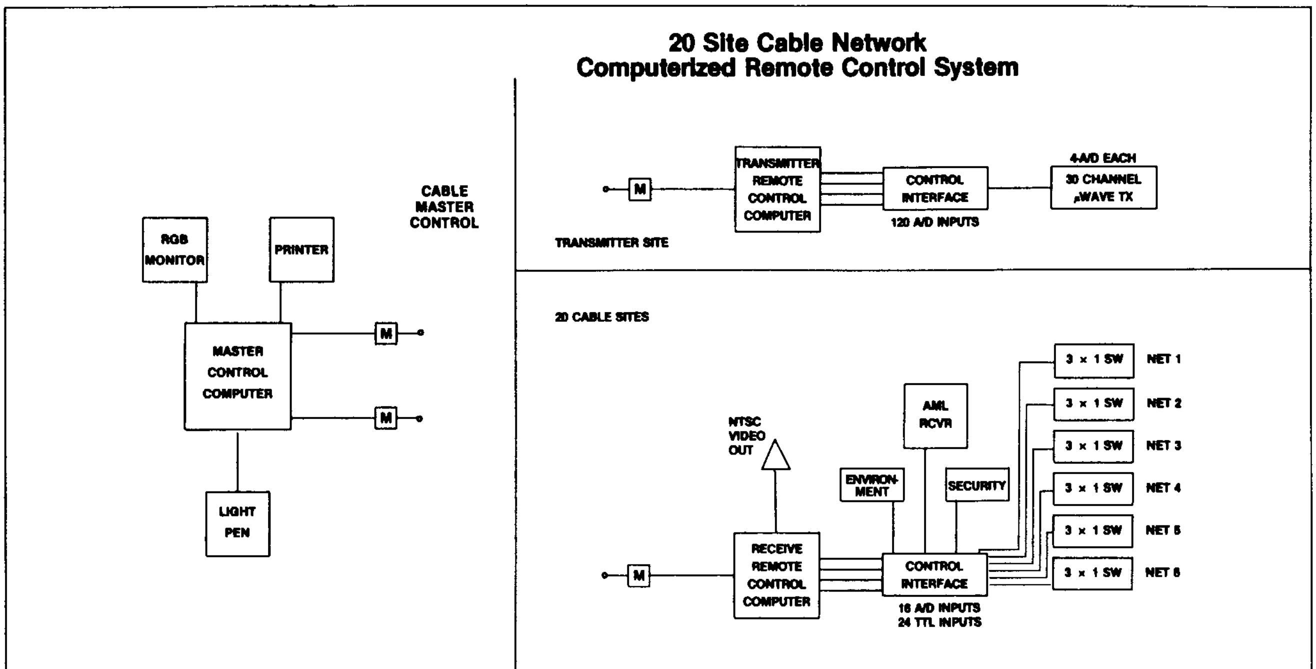


Display

Display of information in a concise, easy to understand format was also an important goal in our needs assessment. We did not want to use the traditional L.E.D. and alarm type display. Instead we chose an R.G.B. monitor to display our reporting information. With the help of multiple colors it was fairly easy to code most information for easy retrieval by the most casual glance. The control center screen was broken into 3 sections. The first being 20 small squares each labeled with the remote site it corresponded to. Within each box a summary of status could be viewed. For instance, the 60V power source used on the AML would be shown as a green 60. But if the AC voltage went outside its predetermined alarm points the new voltage, say 50, would be in red. Also, in each box is the time of the last communication. The second section of the screen was reserved for commands and system status. This area contains "buttons", illuminated squares that when "depressed" by light pen, command the software to carry out preset functions. For instance, the dial button, when depressed, sets the control site computer to call a remote site. After depressing dial, the light pen is then put against the square that has the desired site name. Once this is done, the computer autodials the remote and retrieves the current status information for display at the control site.

The third screen section will display this information in its expanded state. All voltages are brought back in their entirety and can be displayed in this area. Additionally, the site can be left on line for active viewing of a particular site's parameters.

At the remote sites, the PC Jr. is capable of an NTSC output. We took advantage of this and put a display routine in the remote site hardware. At the remote, all system parameters are displayed on one screen in logical order. The same color coding is used - red for alarm, blue, green or yellow denotes normal operation.



SPECIAL FUNCTIONS

DAILY PRINTOUT OF LIST OF NETWORK SWITCHING INFORMATION FOR EACH SITE.

DAILY PRINTOUT OF LIST OF NETWORK SWITCHING DISCREPANCIES.

DAILY PRINTOUT OF LIST OF ALL FAULT OCCURRENCE INFORMATION.

STORAGE AND ANALYSIS OF FAULT OCCURRENCE INFORMATION.

TTL INPUTS

HI LOC
LO LOC
DC SUPPLY
18 NET SW POS.

A/D INPUTS

AC LINE
24 VDC PSU
20 VDC PSU
PHASE LOC
SOURCE LOC
AGC
TEMPERATURE
SOURCE ALARM

SPECIAL FUNCTIONS

STORAGE OF ALL NETWORK SWITCHES AND TIME OF SWITCH

DAILY CALL TO MASTER TO DOWNLOAD SWITCHING INFORMATION

STORAGE OF ALL FAULTS, TIME OF FAULT AND DURATION

CALLS MASTER AT TIME OF FAULT AND TIME FAULT CLEARS

DAILY CALL TO MASTER TO DOWNLOAD FAULT INFORMATION

Light Pen

Light Pen software is also run in machine assembly language. This routine is straight forward and available from several vendors. The importance of the light pen for our application is the reduction in computer literacy required for operation. One problem we found with most computer based systems is the need for extensive operator training. We strove for simplicity in operation as a key point in software design. Once the program is up and running all commands are activated by light pen control.

I/O

I/O, or inputs and outputs, are also on the computer buss using machine language. When looking for an interface vendor it was important to determine what language they used for communication to the main program. Many of the interface vendors supply support software for interpretation of their data. We chose a vendor that would give us the most basic level of interface. By using machine language, directly between the main program and the I/O, we are able to save processing time. We found that by speeding up the simple communication tasks, the software was more user friendly and all around less frustrating for the operator.

Printer

Printer tasks are accomplished with a small EPSON dot matrix printer. Whenever there is out of specification data, the screen changes and the information is dumped to the printer for hard copy record. Both the alarm and the time of day are recorded. In the event that an alarm is cleared, that also is posted to the printer.

The Central Program

The Central Program ties each of these auxiliary routines together into a cohesive remote control and monitoring system. When the program is loaded from disk into memory, a RAM drive is created. This saves the computer from running the disk drive each time new screen information is needed. Software response time is also greatly enhanced by the increased access speed of a RAM drive.

The main program contains the lookup tables and multipliers for each of the I/O ports and light pen. Therefore, when a voltage test point is outside the capture range of our A/D (analog to data) converter the software can compensate for any external voltage dividers used. This is an important feature as it allows us the flexibility of changing input values without worry of calibration problems.

The main program is quite simple in its routine. Its basic responsibility is to keep track of time. Between each clock cycle the program looks to see if anything has changed with the other routines. For instance, a light pen interrupt would be present if someone entered a command. The program gets the screen coordinates for the pen interrupt and goes to a look up table for directions. In the look up table it might say dial. If so, the main program would then tell the communication program to ready itself for autodial and so on. Each time a status is changed, the program simply looks up what it is supposed to do in the table and follows out that command.

The importance of this design is that Joe has left us the capability to change the software by simply adding points of reference to the look up table. When we went to add more features, it was a simple matter of changing the look up table and the auxiliary program associated with the function desired.

For our application, phone line costs are of paramount concern. In an effort to conserve costs we are using autodial modems. Fortunately, we have been able to keep all of our sites within the calling zone of our local Bell operating company. I can see other applications where this may not be possible making the flexibility in calling routines a nice feature. By having a microcomputer at each monitoring site we are able to save data and make decisions on a communications emergency. When a parameter goes to an alarm status the computer is forced into a dial routine, sending only that fault data to the central computer. Hopefully, though, we will not be receiving alarms from every site daily. Because of this, we built in a "handshake" routine that tells the remote site to call every three hours. This time span was an arbitrary selection and can be changed depending on the cost of each phone call. The handshake takes less than 5 seconds, this keeps the control site computer available to receive calls from other sites. If a site does not report within its three hour time frame, the central computer initiates a call to the remote. Failing a connection, the central computer puts up a "no communications" alarm.

Nightly the central computer calls out to each remote site for a data "dump". This is done between 1:00AM and 6:00AM. During the dump, the remote site sends it's logs of switching changes from local TVRO to the microwave interconnect. This information is then compared against local switches for a discrepency log. During a typical day, we save approximately 16K of switch data in RAM. Using 1200 baud modems, the system takes about 5 minutes to send and verify all of its information.

If during a data dump or any online period another remote station calls with an emergency, that remote site will get a busy signal. As we only have one input communication port at this time, that remote site simply redials until it gets through.

The next step in our system development will be saving all data to a hard disk drive. We are now working out the details of a trend analysis program. It seems obvious that, as we have all of this raw data on the micro, a natural extension of the system is trend analysis. By capturing all of the data in a file labeled with the site name and date we will be able to go back and retrieve any number of statistical data runs. Using an external program and graphing the information it should be easy to interpolate the information into a forecast. For instance, an STX-141 transmitter tube's current and voltage could be plotted on an X,Y graph showing us the rate of decay in the klystron tube. Hopefully we will be able to predict the tube failure beforehand and thereby saving expensive down time and express freight from the Hughes Microwave plant in California. We hope to finish up this part of the system by year's end.

HARDWARE

When it became apparent that we had software that would answer most of our problems we began hunting down the parts necessary to interface the IBM PC and PC Jr. to the outside world. At first glance we considered building in house the necessary interface boards to acquisition the data. The following list was made identifying the parameters of an interface module.

Rack Frame

- °A rack mountable unit to support both the interface and the unrackable PC Jr.
- °Mother board configuration to allow expansion and exchange and back up of parts.
- °User addressable memory location by dip switches on mother board.

°Ability to stack several units for increased monitoring capabilities.
°Easy to wire back plane, split cylinder type punch down connectors.
°A common numerator for expansion. (48 was chosen)

Analog to Data

The Analog to Data conversion A/D is one of the most important inputs in our application. On the Hughes AML microwave equipment, all alarms and test points are analog voltages. Because the computer can not read an analog voltage directly, the interface must convert the common voltage to a digital number for computation. As the software was being developed, it was decided that all voltages should be read directly, leaving conversion to the software running in the micro. This seemed most flexible and has proven to be quite useful. The following list outlines the important parameters to solve our application problem.

A/D

°A minimum of 16 A/D inputs.
°Differential inputs, to avoid ground loops between equipment, and to allow for more accurate metering.
°12 bit resolution giving us a 4096 scale divider.
°Jumper selectable input ranges from .5 Vdc to 20Vdc.
°A processing rate of at least 10 channels per second. While this rate is not considered fast, money can be saved by making fewer tests per second.
°Use a precision multicurrent temperature compensated zener voltage reference for most accurate test reference.
°Measurement accuracy should be within 2%.
°DC inputs only, all AC externally rectified to reduce risks to technicians working around backplane.
°Peripheral interface converts all measurements directly to machine language for connection to PC boss.
°Leave all offsets, linear or logarhithmic slopes to be figured by computer software program.

Status Inputs

Status Inputs are another important feature for monitoring the positions of the audio/video switchers at certain sites. We can also use TTL inputs for checking a variety of alarms and status conditions. The following list defines what we considered essential in our application.

°A minimum of 16 inputs per card, a multiple of our 48 possible points in a rack frame.
°High level inputs, jumper selectable up to 24 volts DC either positive or negative in polarity.
°TTL level inputs, an industry standard used by most manufacturers.
°Contact closure input, where relays are closed for status indication.
°Opto coupled inputs to protect the computer from external voltage spike, technician error, and reducing ground loop problems between equipment.
°Use of an onboard peripheral interface and adapter to convert input status to machine language for interpolation by computer program.

Control Outputs

Control outputs are a future addition that we want flexibility in adding. While we have no current need to control equipment at the remote sites, there may come a time when we want to perform simple remote controls i.e. changing an audio/video switch, switching to backup receivers, or controlling test equipment. For our applications, we could foresee relays providing the most flexible point of control. A few of the desired features were:

°Single pole double throw relays.
°Have both poles and wiper on back plane for normally open or normally closed wiring.
°Loose power and all relays normalize.
°Better the 500V isolation between contact and coil for surge protection.
°Operating power limited to 24V AC or DC 1 amp current, all controls needing higher voltage or current would be done with off board relays.
°Peripheral interface adapter to convert relay information to machine language.

With this basic design criteria set out, we looked through "Byte Magazine" for potential suppliers. We selected a local firm that was willing to "customize" their product to our needs. Electromation Inc., in Circle Pines, Minnesota was able to put together what we needed at a modest cost. They also were able to deliver a few bells and whistles that we had not really contemplated. The most important was their Failsafe module.

Failsafe

Failsafe is an important feature in a control system. The failsafe module was built for broadcasters that need to meet certain FCC rules for remote control. We found that its 'reboot' feature would be a lifesaver for us.

When there is spurious electricity, or a brown out, a term that means partial electricity, a computer can lock up the software, halting any continued operation. As a means to combat this problem there are several vendors that supply U.P.S., Uninterruptable Power Supply, for brown outs and surge protection for spurious electrical damage. While the failsafe card will not protect the computer from electrical damage, it will cause the computer to go into a reboot sequence. If communications stop between the interface unit and micro, the failsafe card will put the relays into a preset mode, user selected by internal dip switch. This feature will be more valuable to sites that use more extended control features. At this time, we plan to use only the reboot section of the card.

SUMMARY

The remote control and monitoring system outlined in these pages has become an integral part of our overall test and maintenance routines. On the expense side, our monthly cost, including operating overhead and depreciating capital, yields a monthly expense of $92.08 per remote site. The dollar savings minimized in outage and response time has paid for the system many times over. By incorporating existing microcomputer technology and common sense software principles, we have been able to insure optimum signal performance to our cable viewers.

I am certain that our needs and applications will change in the future. The system design principles we have implemented will insure flexibility to meet our needs well beyond the 5 year depreciation of the equipment.

ACKNOWLEDGEMENTS

It is important to mention that this monitoring system was the fruits of many individuals labor. The entire engineering staff at Midwest Cable Satellite, Inc. pitched in to make the project a reality.

Also the unique and personal attention we received from Joseph M. Soll, President, CAT Systems, Inc., New York, and David C. Lunder, President, Electromation, Inc., Minnesota, were instrumental in putting the project past the blackboard stage and into the cable headends.

REMOTE DIAGNOSTICS FOR OFF PREMISES CABLE SYSTEMS

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ABSTRACT

Distributed intelligence in off-premises addressable CATV systems makes remote diagnostics to the module level fast and easy. Our goal in designing our system was to allow the service technician to troubleshoot a system problem within 15 minutes using a minimum of test equipment.

In order to accomplish this goal, we designed automatic tests which are performed by distributed microprocessor-based controller modules. Each module is able to test its own components, communications with the headend computer, communications and control of the tuners for each subscriber. and the subscriber interface electronics.

INTRODUCTION

Diagnosing off-premises addressable CATV systems requires the ability to interpret the diagnostic information provided by the system and to perform some simple tests. In order to understand the communications and control pathways throughout the system, an overview of the system architecture is given.

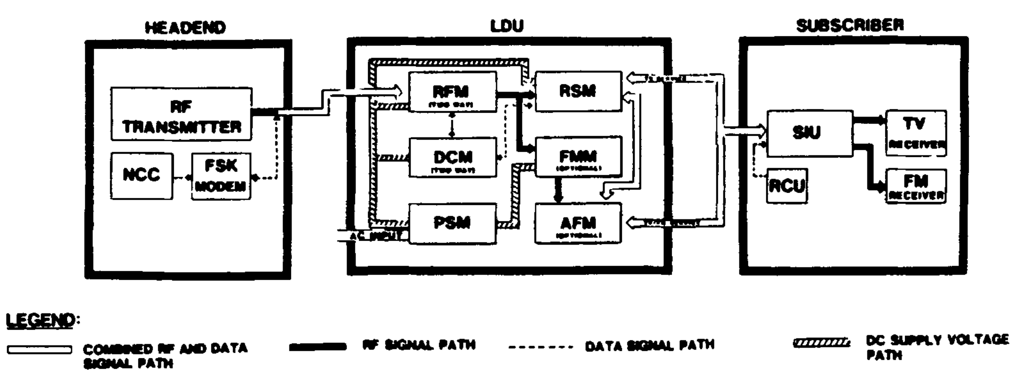
Next, the test capabilities of each system level are discussed. This section includes a description of the automatic tests performed by the distributed microprocessor-based controller modules at each hub. The remote switching modules and the subscriber equipment also provide diagnostic information which is stored in the digital control module.

System diagnostics are then described for a two-way system and for a one-way system. Special test equipment which enables test initiation and monitoring is also described. Results of the testing phases, visable via indicator lights and reports available to the field technician and directly to the operator at the headend in a two-way system. are explained.

Finally troubleshooting procedures are detailed which enable fault isolation to the defective module or communication path. There is a separate section on diagnosing problems at each system level.

SYSTEM DESCRIPTION

The CATV distribution system discussed is an off-premises star-switched system. The major components are a headend computer, the cable plant, the local distribution units, and subscriber equipment (Figure 1).



1. System Architecture

The headend computer is typically a minicomputer that contains the entire subscriber database and controls the network from a central location. The headend computer may communicate with thousands of local distribution units or hubs. It initiates all communications with the various hubs, which are individually addressable. The headend computer may also broadcast messages to all hubs simultaneously.

The power behind star-switched systems is the distributed intelligence at each local distribution unit or hub. Each hub contains a Digital Control Module and a Remote Switching Module with a tuner for each subscriber. Each hub can control the service for 8, 16, or 32 subscriber TV sets.

The Digital Control Module is a microprocessor-based control card with enough memory to keep track of subscriber service levels, diagnostic information, and special purchase information for 2-way systems. The contents of memory are super-cap backed to prevent information loss in all but extended power outages.

A one-way system means that communications travel from the headend computer to the Digital Control Module. A two-way system means that communications travel in both directions. The headend computer always initiates the communications with a particular hub.

The subscriber equipment consists of a drop cable into the home and a Subscriber Interface Unit for each TV. The Subscriber Interface Unit is a simple, low-cost microprocessor-controlled box with a keyboard and a display to allow the subscriber to access TV channels.

The Subscriber Interface Unit sends all channel requests up the drop cable to the Digital Control Module. Since the Digital Control Module contains all of the subscriber service levels, it determines whether the actual channel or a default channel will be sent to the subscriber. It then sends the appropriate information to the tuner and the signal is sent down the drop to the Subscriber Interface Unit and from there to the TV. Communication is one-way from the Subscriber Interface Unit to the Digital Control Module.

TEST CAPABILITIES

The purpose of system diagnostics is to allow the easy tracking of problems to a particular module in the system. This module can then be substituted, and the problem fixed. Each module within the system performs some kind of communications checking and/or self diagnostics.

RF Modem Diagnostics

The RF modem module, within the local distribution unit, interfaces the headend computer and the Digital Control Module. Its green indicator light is lit when the RF carrier is present. If the light is not on, communication has been lost.

Digital Control Module Diagnostics

The Digital Control Module performs diagnostics on itself upon receipt of a diagnostic command from the Local Control Computer or the headend computer or whenever its reset button is pushed. There are three LEDs on the front of the module that indicate the test in progress. The final state of the LEDs indicates whether the unit failed a test or is functioning normally.

The first series of tests checks the internal components of the Digital Control Module such as memory, timers, transmitters and receivers. Three indicator lights on the front panel indicate the component that has failed.

The next test verifies and stores the result of a communications test with each Remote Switching Module. If a Remote Switching Module fails to respond to a handshake test, its indicator light is lit.

The final test determines whether the Digital Control Module is connected to the Network Control Computer or a Local Control Computer. The current status is stored and displayed on the front panel indicators. The status is updated continuously.

The Digital Control Module also expects to receive a periodic signal from each Subscriber Interface Unit. If this signal is not received, the failure is recorded and the indicator light on the corresponding Remote Switching Module is lit until the Subscriber Interface Unit signal is restored.

Remote Switching Module Diagnostics

Each Remote Switching Module has an LED which indicates the results of a Digital Control Module to Remote Switching Module communications check as well as the status of the subscriber equipment at all times.

When a Digital Control Module is reset or receives a diagnostic command, it checks the communications path with each Remote Switching Module. This verifies the integrity of the backplane and line drivers on the Digital Control Module card as well as the functionality of the Remote Switching Module itself. If an Remote Switching Module fails this test, its LED remains on and the failure is recorded by the Digital Control Module. The failure will then appear in later test reports.

Subscriber Interface Unit Diagnostics

When a Subscriber Interface Unit is powered up, it performs a series of self checks to verify that its modulator and IR receiver are working, that there are no stuck keys, and that all display segments may be seen. If a component fails, a corresponding message is displayed on the front panel.

Subscriber equipment testing is in operation continously in that a periodic signal must be received from every Subscriber Interface Unit to indicate that it is functioning. This signal is sent from the Subscriber Interface Unit at all times even if the TV is turned off. This signal will also demonstrate the integrity of the drop to the subscriber.

If this signal is not received for a few seconds, the LED in the corresponding Remote Switching Module is lit to indicate a subscriber communications failure and the failure is recorded in the Digital Control Module.

TWO-WAY SYSTEMS DIAGNOSTICS

Both one-way and two-way systems contain sophisticated diagnostic capabilities. In a two-way system, the headend computer can tell whether or not it is communicating with a Digital Control Module at the hub. This is done by sending a command and receiving a response.

In a two-way system, the diagnostic information may be sent directly from the Digital Control Module to the Network Control Computer located at the headend. The diagnostic reports that were stored in the Digital Control Module are available to the system operator on the headend computer. This means that most problems may be diagnosed before rolling a truck to the site. When a truck must be sent, the field technician will know which modules must be replaced to fix the problem.

The actual subscriber service levels as well as the current status of the Subscriber Interface Unit may be read from the Digital Control Module. The status indicates whether the Subscriber Interface Unit is active or failed, on or off, on cable A or B, on the default channel, or on an enabled channel. The service level check indicates which channels are enabled, disabled, or parentally locked.

With this information, a good portion of received trouble calls may be traced to errors or confusion about subscriber service levels or problems or confusion using the Subscriber Interface Unit. The operator can ask the subscriber to select a channel and verify that the subscriber actually receives it.

ONE-WAY SYSTEM DIAGNOSTICS

In a one-way system, headend to hub communications can be verified at the Local Distribution Unit, by watching the Digital Control Module perform a command such as a reset. This is because there are several lights on the hub modules which will flash during reset. In addition a light on each Remote Switching Module flashes as the handshake test is performed.

Although the indicator lights are normally sufficient to trouble shoot problems at the Local Distribution Unit, more extensive reports may be displayed and printed using a Local Control Computer. This portable, battery-operated unit is attached to the Digital Control Module where the modem is normally attached. An LED on the Digital Control Module signals that the Local Control Computer has been properly installed.

The Local Control Computer can gather the same diagnostic information available to the headend computer in a two-way system. These diagnostic reports show the functionality of the Digital Control Module itself, the status of the remote switching modules, whether they have failed or may be disabled, the status of the Subscriber Interface Units and the communication path integrity between the various modules.

The diagnostic information sent to the local control computer is displayed on a screen and may also be printed via the self-contained printer. This is one of the reports which can be produced(Figure 2).

```
    DIAGNOSTIC
      REPORT
 01/10/86 15:46:42
ADDR :  300
DCM II
LED CODE:  1
  DIAGNOSTIC MODE
DF CHAN =  10
FAILED RSMS:

ENABLED RSMS:
 1  2  3  4  5  6  7
  8  9  10  11  12
 13  14  15  16
REMOTES:
 6
FAILED SIUS:
 1  5  7  8  9  11
 13  14  15  16
INOPER SIUS:

MODEM STATUS:
  DSR ABSENT
PROM CRC = 37C3hex
TBL A CRC = 4BF2hex
TBL B CRC = 4BF2hex
COMMAND? /PR
```

2. Local Control Computer Diagnostic Report

This report allows a technician to easily locate and document the trouble. The site address and date and time are at the top of the report.

Another report, called a subscriber service level check, displays current service levels and the enabled/disabled status of the equipment that provides service to the selected subscriber (Figure 3).

```
   SERVICE FOR
     RSM# 6
    01/10/86
    15:44:18

ADDR :  300
POWER ON
CABLE A
DESCRAMB DISABLED
RELAY OFF
SIU ALIVE
HANDSHAKE LOW
FM  ENABLED
RBG ENABLED
RSM ENABLED
BSM ENABLED

 <-CHANNEL STATUS->

  1- 10:LLLLLEEEEE
 11- 20:EEEEEEEEEE
 21- 30:EEEEEEEEEE
 31- 40:DDDDDDDDDD
 41- 50:DDDDDDDDDD
 51- 60:DDDDDDDDDD
 61- 70:DDDDDDDDDD
 71- 80:DDDDDDDDDD
 81- 90:DDDDDDDDDD
 91-100:DDDDDDDDDD
101-110:DDDDDDDDDD
111-120:DDDDDDDDDD
121-130:DDDDDDDDDD
131-140:DDDDDDDDDD
141-150:DDDDDDDDDD
151-160:DDDDDDDDDD
REMOTE ENABLED
PAR CODE =  4 5 3 6
COMMAND? /PR
```

3. Local Control Computer Subscriber Service Report

This report allows a technician to easily verify discrepancies in subscriber service levels. The site address and date and time are at the top of the report.

TROUBLESHOOTING PROCEDURES

Specific troubleshooting techniques enable the quick determination of faulty modules. The following procedure is tailored for our star-switched system.

Standard diagnostic tools such as a Field Strength Meter, a field Subscriber Interface Unit, a Multimeter and the diagnostic LEDs provided on the modules should enable the service technician to troubleshoot most problems occurring within the system. Some percentage of problems will require the technician to use a Local Control Computer.

At the Office

Before the technician leaves the office, the database should be checked to ensure that the hub has been initialized properly. If the database at the headend computer is correct, then proceed. Otherwise, correct the problem at the headend and transmit the new information to the hub.

If the system is two-way, establish communications with the hub. Verify that all of the modules are working via a diagnostic command. Check the actual status of the Subscriber Interface Unit.

If the problem remains, or if the system is one-way only, go to the Local Distribution Unit where the subscriber's off-premises electronics are located. If the subscriber's complaint is relative to the reception of a particular tier, skip to the section covering headend computer to Digital Control Module communications problems.

At the Local Distribution Unit

Check out the power supply, modem, and the RF levels at the test points provided. Check for terminations or unauthorized connections. Inspect the Digital Control Module, Remote Switching Module, and interconnect cables for any obvious physical or mechanical problems. Look at the LEDs on the Digital Control Module; they should be in the normal running state.

Digital Control Module Diagnostics

Reset the Digital Control Module by pressing the reset button. Do the lights go through a sequence ending with all lights off on the Digital Control Module? If not, do the following steps.

1. Reseat the Digital Control Module in the back plane connector.
2. Check that the connector from the modem is correctly installed on the Digital Control Module connector.
3. Reseat the power supply on the backplane.
4. Repeat the reset command.

If the lights still do not sequence, then replace the Digital Control Module.

Remote Switching Module Diagnostics

Press the reset button on the Digital Control Module. Do all of the Remote Switching Module lights flash? If no lights flash on any Remote Switching Module, then perform the following steps.

1. Reseat the power supplies in the backplanes.
2. Replace the Digital Control Module.
3. Reset the Digital Control Module.

If still no lights flash, then replace the backplane. If only one or a few (less than all) of Remote Switching Module LEDs fail to flash, then do the following.

4. Replace those Remote Switching Modules.
5. Repeat the Digital Control Module reset.

If a Remote Switching Module light still does not flash then replace the backplane in which it is located. The Remote Switching Module was probably good.

Subscriber Interface Unit Diagnostics

Wait for a few minutes after the Digital Control Module is reset. Look at the LED(s) on the Remote Switching Module(s) for the subscriber. Did the light(s) come on? If so, then the Remote Switching Module(s) have powered down due to a lack of "keep alive" signal from the Subscriber Interface Unit(s). Do the following.

1. Check that the subscriber cable is securely fastened to the Remote Switching Module.
2. Disconnect the subscriber's Subscriber Interface Unit and connect a known working, battery-powered field Subscriber Interface Unit.
3. Use the field Subscriber Interface Unit to change channels making sure that it is properly set for first or second-set mode.

Does the Remote Switching Module light flash? If the light flashes, then verify the correct RF operating level. If the light does not flash, replace the Remote Switching Module and repeat the Subscriber Interface Unit diagnostics.

Headend Computer - Digital Control Module Diagnostics

Although the database shows the proper tiering levels for the subscriber, the information may not have reached the Digital Control Module from the headend computer. To verify the communications path:

1. Check that the green LED on the RF modem is on.

If the LED is on, check that the interconnect cable between the RF modem and the Digital Control Module is correctly installed. If the LED is not on, verify the presence of modem carrier by using a spectrum analyzer. If the RF modem carrier level is measured to be within specification and the green LED does not light, then replace the modem.

2. Ask the office to send a reset command to the Digital Control Module.

If the reset occurs, verified by the lights sequencing on the Digital Control Module and all Remote Switching Modules, then communications are intact. If the lights do not sequence then do the following.

1. Replace the Digital Control Module/RF modem interconnect cable.
2. Ask the office to send a reset command to the Digital Control Module.
3. If the lights do not sequence then check the right angled F connector and the RF modem.

If the Digital Control Module does not respond, then go to the Digital Control Module Diagnostics section. If the Digital Control Module responds, then replace the modem and the interconnect cable.

If problems still persist, the Local Control Computer may be used for more extensive tests as follows.

Local Control Unit Problem Verification and Diagnosis

1. Connect the Local Control Computer to the Digital Control Module.
2. Send a transmit address command to the Digital Control Module from the Local Control Computer using the Digital Control Module address or a global address.

If the Digital Control Module responds to a global command but not to its own address, then replace the address PROM.

3. Perform a diagnostic command making sure to produce a hard copy with the printer.
4. Perform a subscriber service check command making sure to produce a hard copy with the printer.
5. Check that all of the headend computer database service levels for the subscriber are the same as those in the Digital Control Module based on the readings just collected.

If not, go to the Headend - Digital Control Module Diagnostics section. If the service level is correct, verify the complaint with the subscriber using the subscriber's Subscriber Interface Unit or the field Subscriber Interface Unit and an Field Strength Meter.

Diagnosis of Equipment at Subscriber's Premises

To determine if the Digital Control Module is responding to Subscriber Interface Unit commands from the subscriber, perform the following.

1. Unplug the TV from the Subscriber Interface Unit and plug it into the wall.
2. Turn the Remote Switching Module off and on from the Subscriber Interface Unit. When the Subscriber Interface Unit is off, the TV should go to white noise or to a blank screen.
3. If the ON/OFF commands work but channel

change commands do not, then change the video and check the tiering information again for accuracy.

4. If the ON/OFF commands do not work, do the following.

   1. Check for Subscriber Interface Unit problems by substituting a known working Subscriber Interface Unit.
   2. Repeat the ON/OFF commands.

If the ON/OFF commands still do not work then the problem is in the drop cable.

CONCLUSION

In conclusion, star-switched CATV distribution systems are easily maintained due to the troubleshooting capabilities inherent with distributed microprocessor intelligence. Most problems are solved within the 15 minute timeframe to the module level using simple tools and without entering the subscriber's premises.

RESIDENTIAL TWO-WAY CABLE APPLICATIONS

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ABSTRACT

Many residential two-way cable plants in existence today are not taking advantage of the revenue opportunities that are available to them. The number of active two-way CATV miles in the past were increasing but are now actually declining. There are many applications that utilize a two-way cable plant and this paper explores three major ones. They are: status monitoring, impulse pay-per-view and data transmission service. The premise is that individually these applications are not currently significant or even cost-effective, but when implemented in combination with each other, could make an attractive and profitable operation.

INTRODUCTION

The CATV industry today has more than 310K two-way capable miles of plant of which only 12% is currently active. Table A shows the growth of CATV plant miles, two-way capable and two-way active miles over the last four years. Although the industry has attempted to implement two-way interactive cable plants, the success rate has been very sparse. While the initial investment for two-way active plant is high (relative to a one-way plant), the long range revenue potential is very attractive. It is this revenue opportunity that can be realized through status monitoring, impulse-pay-per-view (IPPV)and data transmission service.

These specific opportunities will be explored in terms of application, costs involved to implement and advantages and disadvantages of each.

PLANT DESIGN

The first place to start is with an explanation of what a two-way active system is. This refers to a plant used to transmit information both up and downstream. The majority of coaxial cable installed today is capable of carrying bi-directional signals. This includes both new-build systems and rebuilds.

Equipment should no longer be a technical stumbling block.
The amplifiers required to bring back the return signal are easy to install, plug-in modules. Technology advances have eliminated many of the earlier technical problems with a two-way plant to the point where the equipment is now very good.

Table A

TWO-WAY MILES

YEAR	TOTAL PLANT (K MILES)	TWO-WAY CAPABLE (K MILES)	% OF TOTAL PLANT (K MILES)	TWO-WAY ACTIVE (K MILES)	%OF TOTAL PLANT (K MILES)	% OF 2-WAY CAPABLE (K MILES)
1982	383	168	44.	29	8.	17.
1983	440	212	48.	43	10.	20.
1984	518	253	49.	72	14.	28.
1985	564	310	55.	68	12.	22.

[P. Kagan 11/30/85 Cable TV Technology]

All current return paths are limited to the 5-30 MHz bandwidth. This small range of bandwidth does constrain a cable operators ability to provide extensive two-way active services.

One potential alternative is to take advantage of the increased bandwidth capability of amplifiers that now operate in the 550-600 MHz range. These upper end frequencies are less affected by noise and interfering signals. The current constraint on this idea is the fact that manufacutrers do not currently have available the high end frequency return amplifier modules. Additionally the return signal transmission in impulse-pay-per-view systems are not designed for other than 5-30 MHz.

Deregulation of the must carry rule should have positive impact on some operators, who could then free up some high end band space of their systems plant for a return path. Here again however, return path hardware must be designed to handle those frequencies.

STATUS MONITORING

Status monitoring and control systems have gone from a luxurious extra to a basic requirement for a cable plant. The present market for status monitoring and control equipment demands technology that can provide information on the overall operating condition of the CATV plant. This system will detect and report faults in a system before disruption of service occurs and control certain amplifier and standby power supply functions for multiple hub systems, both locally and remotely from the master headend.

The primary objectives of status monitoring and control systems are:

- increased plant reliability through reduced downtime
- reduced maintenance costs
- knowledge of equipment operation over entire plant
- better utilization of manpower for maintenance and system operations
- prevention of catastrophic failures through trend analysis and alarm history

These objectives are all very basic and meaningful to operators on a day to day basis.

Status monitoring and control systems have application for the functions as shown in Table B.

These functions are critical to control and can improve the performance and reliability of a cable system.

When considering implementation of a status monitoring and control system, costs, advantages and disadvantages must be considered. Unfortunately, an easy economic analysis of this is not practical. This is due in part to the variable cost, based on system size, condition of the plant, and plant operating costs. An operator should, however, attempt to identify on an individual basis, what the bottom line benefit should be.

The equipment cost would be a headend computer such as an IBM PC plus plug-in modules for each amplifier and standby power supply. This cost will vary directly with the cable plant size.

Table B

STATUS MONITORING FUNCTIONS

EQUIPMENT	FUNCTIONS MONITORED AND CONTROLLED
Amplifier	• Forward RF level measurements (carrier frequency) • Reverse RF level measurements (carrier frequency) • Control of return feeder switch • Attenuating return feeder path • Controlling other amplifier switches • Monitor intrusion via amplifier housing tamper switch
Standby Power Supply (designed & mounted internally to the type of power supply)	• Battery voltages, system load levels and measure temperature • Cabinet tampering • Charger/inverter malfunctions • AC/standby switchover status

Some of the advantages, however, from this system can on an individual system basis be turned into dollar savings. This includes the savings from reduced truck rolls, the time saved in troubleshooting (go directly to identified trouble area) and increased overall operating efficiency. Additionally, newer status monitoring and control systems have reduced the number of adjustments required to set up and maintain a system. The operator will need to assess his own number of field failures, average trouble shooting time and number of errant truck rolls and assign a dollar amount to each.

Given this economic analysis is favorable, the operator should also consider some disadvantages, beginning with the capital required to install a status monitoring and control systems. Another major concern should be that this monitoring and control system is another piece of equipment to maintain (including everywhere in his system) and if he doesn't believe the reliability is very good this additional system may be more of a burden than a benefit. This could translate into more problems due to faulty alarms.

As one can see, there is not a clear cut numerical analysis to determine the need for and value of a status monitoring and control system. A status montoring and control system offers the operator an instant overview of a system's critical components, provides a smooth running system and, last but not least, peace of mind.

IMPULSE PAY-PER-VIEW (IPPV)

Having an active two-way cable plant offers an operator the opportunity to offer his subscribers pay-per-view program services. There are two distinct technologies for these services: real-time advance order, and store and forward. In either case, the cable operator's intervention during the ordering cycle is eliminated.

All of the real-time systems require the establishment of a closed-loop communication link between the subscriber and the headend computer system before a subscriber can view a pay-per-view program. The transaction time is not instantaneous, and closed-loop communications for order processing is required for each participating subscriber. It is not unreasonable to expect that with a substantial subscriber base, subscribers will have to order programs in advance of the showing to guarantee sufficient time for processing and communication of program authorization.

Real-time systems also demand that the entire ordering system be operational prior to the program, or potential orders will be lost. A last minute equipment or communication link failure will result in lost revenue opportunity and frustrated subscribers.

Seeking to overcome the limitations of real-time ordering systems, a pay-per-view technology known as store and forward was designed. This ordering system can provide an effective solution to anticipated operational problems associated with traffic bottlenecks caused by peak order loads. The store and forward technology poses no limits to the number subscribers that can order an event, and provides instantaneous program authorization for immediate subscriber viewing.

In a store and forward system, converters are pre-loaded with purchase credits against which subscribers order PPV programming. The subscriber orders a PPV program by entering a secret personal identification code, either directly on the converter or using the handheld remote unit. If the subscriber has sufficient credit, he receives instant authorization to view the program. The converter is not required to communicate at that immediate time with the headend system in order for programs to be cleared for viewing. At the time a program is purchased, a program identifier and time stamp is stored in the converter's non-volatile memory. Later, on a non-real-time basis, the addressable controller collects this program purchase information for subsequent billing. Every subscriber in the cable system can order an "event" or program up to the last minute before a showing, or even during the first few minutes of a program, depending on the cut-off ordering time determined by the cable operator. In this way, consumers are able to buy on a true "impulse" basis. The store and forward technique is the only IPPV scheme available today that does not require real-time communication and data processing; it totally avoids real-time bottlenecks in the control system.

The capital and variable costs associated with a two-way cable IPPV system are basically, (1) the additional cost to make the cable plant two-way active, and (2) the two-way terminals (converters). There is no real variable cost on a per event basis for a two-way IPPV system versus additional costs for some one-way IPPV systems.

The key advantages and disadvantages are shown in Table C.

DATA TRANSMISSION

A subsplit two-way residential plant can serve the needs of banks and other businesses with multiple offices in the franchise area. Transmission of data is another opportunity for the cable operator to generate revenue.

From a system standpoint, what is required to generate data revenues is a network with two-way capability and at least one free channel in the forward (downstream) direction corresponding to a reverse channel offset by 156.25 MHz or 192.25 MHz.

Assuming the two-way active plant exists, the additional costs involved to transmit data include: installation of additional headend equipment, supplying data modems and providing drops to business customers.

For the system headend, each 6 MHz channel requires one headend frequency transverter to translate incoming (upstream) low frequencies to higher outgoing (downstream) frequencies for communication between users.

The number of data modems needed varies with the number of channels used, number of multi-point circuits and the percentage of available data circuits used.

The last capital expense is providing cable drops to the business customers. The cost of providing a drop to a business user must be estimated on an individual basis.

In addition to capital expenses, there will be additional operating expenses which include: personnel and administrative, and maintenance and spare parts. Some of these expenses will vary with the number of data channels used.

There are many factors that have an impact on the amount of revenues that can be expected from business data transmission are; data speed, local phone alternatives, quantity of lines needed and length of contract.

Transmitting business data over residential cable systems is financially attractive for existing systems that can allocate two or more TV channel pairs for data. Using two channels, payback could occur in the range of 2.5 years. Using four channels reduces payback to approximately 18 months. This is achieved assuming a 70% use of available data circuits. Any increased use of available circuits will provide more rapid payback. This analysis is intentionally left brief due to the many variations and tax implications for each operator. Depreciation, investment tax credits, tax savings (or debits) are not reflected in these projections.

In the legislative arena, the controversy surrounding regulation of programming services has become more definitive with the Cable Act of 1984. Regarding data, however, the Act did little to clarify the authority of State Public Utility Commissions to prohibit or regulate services. The FCC has shown, however, that it will overrride state PUC's that try to impede this fledgling business from offering its services. In a recent ruling, the FCC stayed an order by the Nebraska State Public Service Commission preventing Cox Communications from offering data services in Omaha via its Comline subsidiary. The FCC argued

TABLE C

Technology	Advantage	Disadvantage
Interactive (Real Time)	. High User Friendliness . No variable cost per event	. High 2-way plant & terminal investment . High 2-way plant maintenance . Limited Peak Order Capability
Store and Forward	. High user Friendliness . Unlimited peak order capability . No variable cost per event	. High 2-way plant & terminal investment

that Comline offers interstate services through its MCI Communications link and that the Nebraska Commission overstepped its bounds.

This ruling, although encouraging, does not definitely state how it will act in future cases. In most cases, it is recommended that cable operators get some sort of reading from the local commission on their position regarding data services over the cable network. While some PUC's are heavily influenced by local telephone companies and seek to discourage such services by cable, others are more favorably disposed and view it as healthy competition.

POTENTIAL APPLICATIONS

The applications for two-way cable continue to expand with interactive services such as home banking and shopping, games, etc. There are currently cable operators taking advantage of their plant capabilities with home security systems, meter reading and energy management systems. While these are in their infancy and high on the learning curve, they should not be abandoned. These applications, while perhaps somewhat in the future, are rapidly approaching a complete home information system.

CONCLUSION

The consolidated review table below shows the current and potential applications for a residential two-way cable plant.

APPLICATION

Status Monitoring
IPPV
Data Transmission
Engergy Management
Home Security
Meter Reading
Home Banking
Home Shopping

All of these applications, when implemented, can be revenue generating for the cable operator in one sense or another. The fact that operating costs can be reduced with status monitoring and subscriber revenue increased with IPPV, make two-way systems viable.

The real benefit to an operator is when he can expand his two-way cable system to include many of these identified applications. The cable operator is currently serving the residential community. The other side of this is the untapped commercial community needing data services. Considering this opportunity, as well as the expanding potential to provide services to its current subscriber base, should make the value of a two-way cable plant very clear.

Progress is made by taking calculated risks and exploring the unknown. A well designed and maintained two-way active cable plant can be a profitable operation.

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STORE AND FORWARD IPPV VIA THE TELEPHONE RETURN PATH

by

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ABSTRACT

Utilizing the public switched telephone network for Impulse Pay-Per-View (IPPV) is an appealing alternative to building and maintaining a two-way cable plant. The telephone system provides a reliable means of communication for both voice and data. What will happen when it is subjected to concentrated peak loads for Impulse Pay-Per-View purchases? The 'store and forward' IPPV system provides a method to eliminate peak loads. The subscriber terminal must be a 'smart' addressable unit with non-volatile memory and auto-dial modem capability. The terminal stores the purchased event service code and time of purchase. At a later time the terminals are commanded to call, in organized 'calling groups', to report their stored purchases. This paper examines the operation of a hybrid cable/telephone IPPV system and how it will work in a real cable system environment.

INTRODUCTION

In order to demonstrate the potential use of a hybrid cable/telephone IPPV operation the entire system will be examined from the scheduling of events to the impulse purchase or "store" to the data collection or "forward" process. The telephone specific considerations will then be examined to show the practical application of the automatic dial modem (terminal) in the subscriber's home. A successful operation will require not only that the data collection process is reliable, but also that it does not interfere with the subscriber's use of the telephone. From the cable operator's point of view the terminals should be relatively easy to install, the system should be automated to avoid billing errors, and it should be easy to maintain.

Some commonly asked questions are :

- What equipment is required for data collection ?
- How are the events scheduled for purchase ?
- What is the maximum rate of collection possible ?
- How many phones/terminals can be installed in a home ?
- Will there be contention with the subscriber's telephone ?
- What is the Installation time required?
- What are the FCC regulations and requirements ?
- How much security is required ?

The answers to these questions and others are the topic of this paper.

TELEPHONE IPPV HARDWARE AND SYSTEM ARCHITECTURE

The telephone IPPV system looks much like the traditional addressable cable system with a few minor additions. One or more incoming telephone lines are installed and attached to as many auto-answer modems. If more than one incoming line is needed a rotary or 'hunting' configuration is installed by the telephone company in the central office so that one telephone number can be used for multiple lines. The auto-answer modems are normally 300 baud since the transaction time is short and this is the most reliable form of data communication over the public switched network. The modems are connected to a telephone controller where the incoming data is collected for later transfer to the billing system. The addressable controller actually has the job of assigning the 'calling groups' for a controlled sequence of data collection with minimum telephone usage and maximum throughput. The telephone controller may actually be part of the addressable controller in smaller systems, or systems with few event offerings.

The home terminal consists of a 'smart' addressable converter with an auto-dial modem and non-volatile memory for storage of the purchase information (data). It is capable of 2-way communication over the telephone and must be registered by the FCC under part 68. It must be capable of distinguishing the event being shown, allow the subscriber to purchase it, keep track of credit usage, and return this data back to the telephone controller on command. Besides being able to dial and communicate, it must also allow the subscriber to have priority use of the telephone.

The rest of the system is likely to be the same as an existing addressable control system with the possible exception of the schedule driven scrambler/encoders. The encoders will store a sequence of event schedules and automatically switch on the exact time to the next control setting in its memory. Each encoder has its own time clock and non-volatile memory storage so that it can survive a power outage and return to its scheduled settings. These time clocks are synchronized by the addressable controller and keep accurate time even with loss of power. This fail-safe method can ensure the maximum protection against lost revenue due to computer down time and power outages. This aspect becomes especially important when offering high-priced blockbusters on a regular basis.

The complete system diagram would be as shown in Figure 1, which shows all of the basic components in a telephone IPPV system.

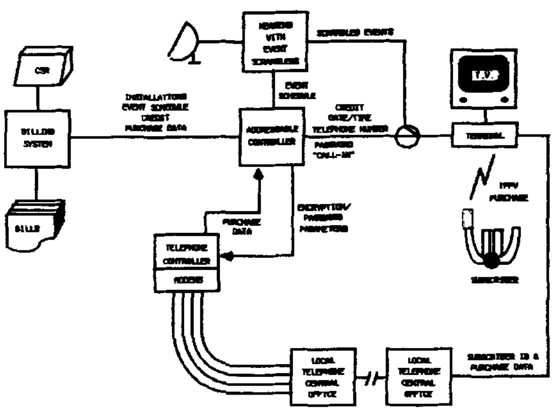

FIGURE 1: I.P.P.V. SYSTEM WITH TELEPHONE RETURN PATH

EVENT SCHEDULING

The source of the IPPV system is the programming material which the cable operator supplies on one or more channels. The event schedule supplied with this programming must be entered into the billing system, the addressable controller, and the headend scramblers/encoders. This schedule consists of a 'service code' for each event with a given 'preview time', 'purchase time', and 'no-purchase time'. The service code is transmitted (in-band) with the scrambled program to identify the purchased event.

The 'preview time' allows the viewer who has not yet purchased to watch a preview segment of the upcoming event with the option to purchase at this time. The 'purchase time' is when the event is no longer viewable by subscribers who have not yet purchased it, and therefore must be purchased to continue viewing. After a predetermined time into the event the 'no-purchase' option may be used to avoid a mistaken purchase for the following event during the end of the current event (see figure 2).

Both the service code and the time of purchase are used to identify a purchased event, so the service code may be re-used at a later time.

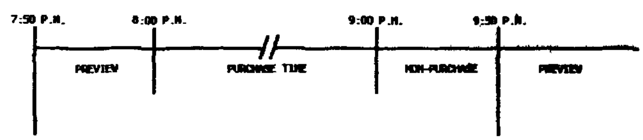

FIGURE 2: EVENT SCHEDULE

IMPULSE PURCHASE OR STORE

The 'store' operation occurs when the subscriber tunes to an event channel and initiates a key sequence to buy the event. Recent studies indicate that subscribers will use this method four times as often as subscribers who must initiate a telephone call to the cable office for the same services.

If the home terminal is 'allowed' to purchase, the event is simply descrambled and the transaction is stored in non-volatile memory. The terminal must verify the following before allowing the purchase:

- Purchase code (PIN) was entered correctly.
- Credit limit is not exceeded.
- Current date and time is known.
- Channel is not parentally controlled.
- Event program is in 'preview' or 'purchase' time.

To help the subscriber and/or cable operator to identify a problem with purchasing, an informative message should be displayed on the terminal. Normally this process is successful and will subsequently appear to the subscriber as an instantaneous authorization by the cable operator to the requested purchase. The terminal will store the following information to log the purchase for collection at a later time :

- Event service code.
- Date and time of purchase.
- Status information (valid, collected, etc.).

DATA COLLECTION OR 'RETURN' PATH

Any two-way IPPV system requires a reliable and effective method to collect purchase transactions for billing. The subscriber must be aware that it is impossible to steal service or avoid the billing process.

The collection process may vary a great deal depending on the number of subscribers, the number of events offered, and the penetration rate of the events. The system design must accomodate a data collection process capable of collecting the data :

1. Within the established billing cycle
2. Before the terminal runs out of storage.
3. Before the terminal security disable.

Since many systems use multiple billing cycles, special considerations may be needed to ensure the timely collection of transactions. If many different events are offered it may be necessary to perform a 'skimming' operation to collect data from the heavy users. Certain security aspects must also be considered in the terminal to ensure that the purchase data is collected within a given timeframe.

When examining the efficiency of data collections in a telephone return path it is obvious that the number of incoming lines should be directly proportional to the amount of data that can be collected in a given period of time. There are many other opportunities to maximize the system throughput which may not be quite as obvious. Among these methods are :

- Require only terminals with purchases to call-in.
- Provide a 'skimming' operation (call-in if > N purchases).
- Overlap calling groups (eliminate dial & connect time).
- Allow for maximizing the usage of incoming lines by providing retries after a busy signal.

These methods can be used to 'tune' the collection process depending on the system size and event penetration.

In actual operation there are several situations that hamper data collection. These are :

- Subscriber's phone is in use.
- Terminal is unplugged from AC power.
- Telephone connection is unplugged or faulty.
- Only one terminal in the home can call-in at a given time.

The system must allow for these conditions by providing multiple (time-shifted) collections and a method to identify the faulty terminals. Additional consideration may be needed to determine the number of phone calls generated from the subscriber's home, especially if they are toll calls.

SYSTEM THROUGHPUT EXAMPLE

It is reasonable to assume that a successful IPPV operation may be running 12 events per day on two channels. It is unlikely that a subscriber would purchase all 24 events in a given day since he can only watch one channel at a time for a period of less than 24 hours. Since the events are reshown it is more likely to assume that an average viewer will purchase two events per week. If the terminal can store 16 events it will then be necessary to collect the transactions for the average subscriber at least once within an eight week period. Assuming that we will collect transactions once a week (8 times more often) and the data collection time is 15 seconds, the following shows the theoretical limit for system throughput with one incoming line :

15 sec/box	=	4 boxes / minute
	=	240 boxes / hour
	=	5,760 boxes / day
	=	40,320 boxes / week

With 10 incoming lines :

	=	57,600 boxes / day
	=	403,200 boxes / week

The total I/O processing power in the latter case is 3 KBaud continuously (10 lines x 300 Baud) with the ability to store 1.3 transactions/second (10 lines x 2 transactions / 15 seconds). This is a moderate job for today's microcomputer with a hard disk. Of course the total load on the telephone system is only 10 to 30 calls continuously.

Since it is impractical to use theoretical limits in real life, system throughput should be cut by the expected inefficiencies. For example:

- 12 hour/day data collection.	50%
- Non-maximized incoming line usage.	5%
- Second pass and special collections.	5%
- Computer or cable system down time.	1%

Keep in mind that the percentage of inefficiency is not always additive and the efficiency of this example would most likely be represented as:

(100 - 50) x 0.95 x 0.95 - 1 = 44.125 %

57,600 boxes/day x 44.125 % = 25,416 boxes/day

If the system size increases beyond the limits of the equipment, another telephone controller can be added in parallel. If it has the same number of incoming lines, the throughput will double.

TERMINAL CALL-IN SEQUENCE

When a terminal is commanded to call-in to report transactions to the cable office it first must determine if it has anything to report. If not, then no attempt to call is made. If so, the terminal must be sure that :

1. The phone is not already in use (either off-hook or dialing).
2. The phone is not ringing.

After determining that the phone is free to use, the following sequence occurs:

1. Take the phone off-hook.
2. Wait for the dial tone.
3. Dial the (downloaded) phone number.
4. Wait for pickup and carrier detect.
5. Receive first command (encrypted).
6. Respond and continue dialogue.
7. Hang up.

This complete process takes approximately 35 seconds under typical circumstances and is illustrated in Figure 3. Ideally the terminal should be capable of relinquishing the line to the subscriber at any time to avoid a conflict. Also, the terminal should be capable of hanging up and redialing after a given period of time if the correct signals were not present the first time (ie. busy signal). The number of retries should be a downloadable parameter.

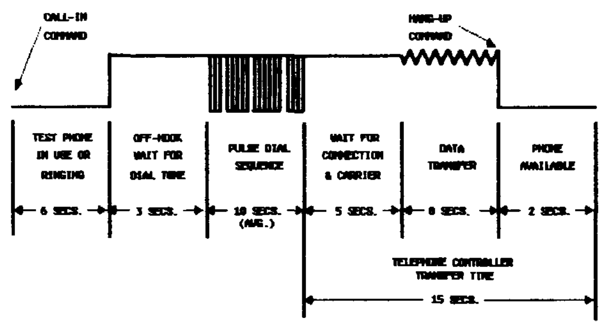

FIGURE 3: CALL-IN AND DATA TRANSFER SEQUENCE

PULSE DIALING AND RINGING

Pulse dialing is normally selected since it is universally available throughout the United States. The dial sequence consists of a series of 100 millisecond 'breaks' and 'makes' for each digit, with a 0.8 second inter-digit gap (see Figure 4). Using these values the time for each digit is:

1 = 0.9 sec	6 = 1.4 sec
2 = 1.0 sec	7 = 1.5 sec
3 = 1.1 sec	8 = 1.6 sec
4 = 1.2 sec	9 = 1.7 sec
5 = 1.3 sec	0 = 1.8 sec

It is easy to see that a telephone number with more 1's than 0's is faster to dial. Some sample numbers are:

123-4567	8.4 sec
555-9000	11.0 sec
1-800-123-4567	14.5 sec

The ringing pulse is an AC signal superimposed on a DC biased level. The ringer frequency, duration, and voltage can vary widely as shown in Figure 5. The terminal must wait up to 6 seconds to determine if the phone is ringing before going off-hook to dial.

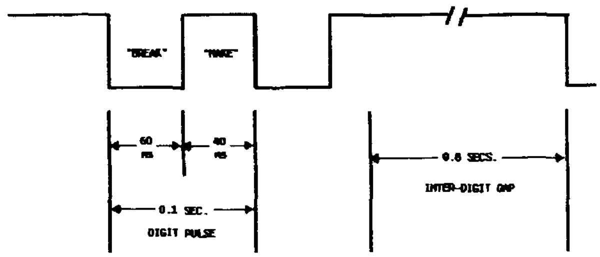

FIGURE 4: DIAL PULSES

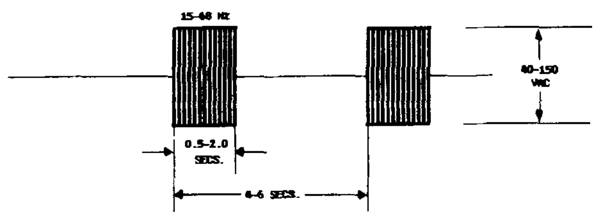

FIGURE 5: RINGER SIGNAL

DATA SECURITY

Since the telephone is widely used by computer hobbyists or 'hackers' it is advisable to add some security to the data transmission. Encryption methods can be used to stifle any attempts at breaking into the data collection scheme. Also both the terminal and the headend should hang-up if the wrong data sequence is received.

Anyone attempting to steal event services by unplugging the telephone connection may find that they will lose their complete service when the terminal realizes that it is unable to communicate. If no events are stored, the terminal will function properly without the telephone connection. If an event is purchased and the terminal fails to call-in after multiple data collection cycles, the security timer will eventually timeout and cause a loss of service until the situation is corrected.

INSTALLATION AND MAINTENANCE

The connection of equipment to the telephone network requires additional training, special tools, and additional hook-up equipment. Although the installation of an extension phone is similar to that of a cable outlet, the system is entirely different in nature and therefore requires some basic knowledge. A simple phone system uses 2 wires called 'tip' and 'ring' to carry the signals for off-hook, dial, ringer, and voice or modem signals. These signals have certain constraints and should be well understood by the installer/troubleshooter. A maximum of five ringer loads (REN) may be connected to a given phone line. Any device registered by the FCC has a REN number listed on the FCC label. Certain voltages are allowable for on-hook and off-hook but these can vary with humidity and may affect the terminal operation. DC voltages can change polarity to indicate toll calls.

A telephone installer will require a voltmeter, a handset ($300.00), and a crimper ($75.00) at a minimum. Recent experience has shown that it is rare to find a telephone jack in close proximity to the television. The additional time required for the telephone installation is roughly estimated at 45 minutes, with most installations requiring wall or carpet fishing. Some good aspects are that the phone connections already exist in the home and the telephone is traditionally reliable.

CONCLUSION

It is easy to conclude that the store and forward IPPV concept, used in conjunction with the telephone return path, represents a realistic and workable approach to the Pay-Per-View business. As with any Pay-Per-View system it is complex and should be well understood by the operating personnel. The system is structured for mostly automated operation with no loading of the telephone network. The processing power has been distributed to the ends of the system where it works best, allowing for instant purchases and minimal processing power at the collection end. The telephone system is reliable and is maintained night and day by the local telephone office. A test market can be created easily and without great expense. If the market exists the system can be expanded to cover virtually any system size.

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SYSTEM CONSIDERATIONS IN APPLICATIONS OF 18 GHz MICROWAVE TO CATV

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Microwave Communications Products

ABSTRACT

When compared to the conventional 12 GHz CARS band microwave, 18 GHz systems suffer from substantially higher rain attenuation and somewhat reduced equipment capability. However, in those instances when an interference free CARS band frequency allocation cannot be obtained, 18 GHz microwave systems can in many cases offer a viable alternative. High power transmitters utilizing specially developed klystron amplifiers have been utilized at a 17 mile range with acceptable link margin. Both 6 MHz wide VSB-AM and 20 MHz wide FM video channels can be accommodated with this type of equipment. Comparisons between 12 GHz and 18 GHz equipments and system performance are presented.

INTRODUCTION

The FCC originally assigned the 12.7 - 12.95 GHz frequency band to the Community Antenna Relay Service (CARS). The utilization of microwave in this frequency band, particularly since 1971 for Local Distribution Service (LDS), has steadily grown until today there are over 100,000 VSB-AM channel paths in the United States. Despite a later expansion of the band to 13.2 GHz, the resulting frequency congestion, particularly in major urban markets, has in some instances led to actual or potential interference between neighboring systems. Recently, the FCC established an 18 GHz frequency plan which provides for both 6 MHz channels suitable for VSB-AM distribution and 20 MHz wide channels suitable for FM. Figure 1 shows this frequency plan. Although the total bandwidth provided in this "18 GHz" plan is 2 GHz wide, the frequencies of greatest interest for U.S. CATV operation would presumably be the 18.14 to 18.58 GHz frequency band allocated to 6 MHz wide channels suitable for VSB-AM video carriage. The wider band FM video channels can be readily accommodated in the adjacent 17.70 to 18.14 GHz band.

While the types of CATV signals which may be carried at 18 GHz are the same as those carried in the 12 GHz CARS band, the propagation conditions at the higher frequency are considerably more severe. Studies are available to provide a fairly firm basis for predicting the affects of rain and multipath at 12 and 18 GHz.[1,2] These are reviewed in the following paragraphs. There follows then a comparison of the recently developed 18 GHz equipment with the more familiar AML transmitters and receivers utilized at 12 GHz. Other factors affecting the microwave link such as antenna performance and waveguide and multiplexing losses are also discussed.

A knowledge of all of the above factors is required to predict the performance of an 18 GHz microwave link. Several typical applications are described. These

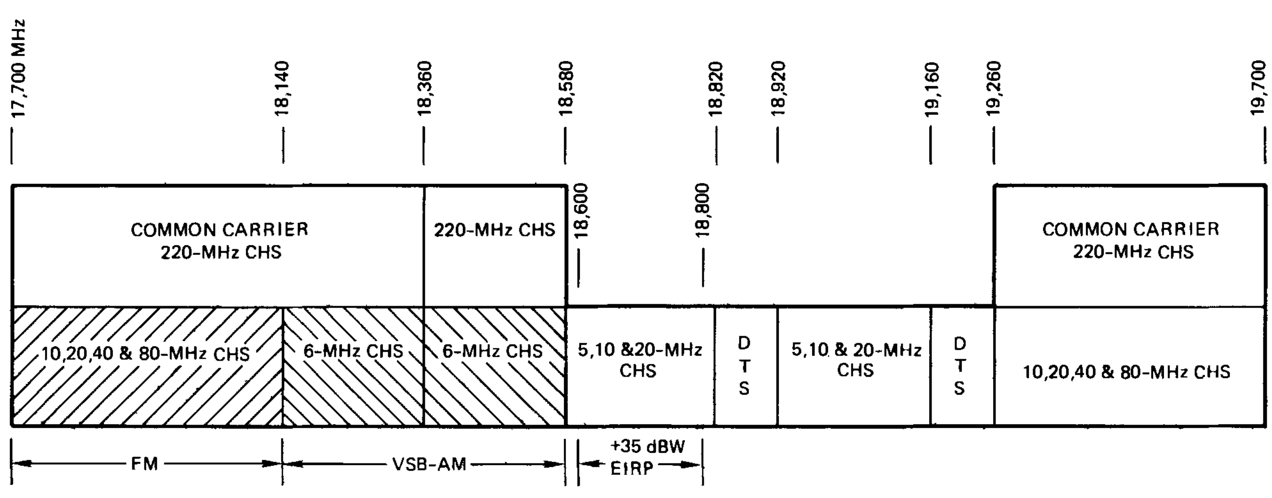

Figure 1 18 GHz spectrum allocation.

illustrate that acceptable link margins can usually be obtained for CATV systems.

PROPAGATION

Extensive experience has been gained in the past 15 years with 12 GHz microwave paths carrying VSB-AM video signals in CATV LDS systems. Video signals are carried in the VSB-AM format in microwave LDS because of the overriding advantages of cost, compatibility with the cable distribution, and spectrum efficiency. Moreover, despite the lack of an "FM S/N improvement" in an AM system, the general experience has been that fade margins as low as 20 dB (to 35 dB C/N) could provide acceptable signal quality and availability in most instances. Exceptions were primarily associated with long paths which paralleled prevailing storm fronts. With this exception, the empirical models used to predict path reliability statistics at 12 GHz have, if anything, been conservative.

Propagation at 18 GHz, although much less familiar to the CATV industry, is not entirely an unknown. Indeed, the initial experiments having a microwave LDS for CATV specifically in mind were carried out at 18 GHz.[3] It was found that even relatively short paths (4.25 miles) in an average weather environment (New York City) were subject on occasion to very deep fades (40 dB). The test results are however compatible with the predictions of the empirical models. What, then, do these models tell us about the relative performance of the atmospheric path at 12 and 18 GHz?

Figure 2 shows the attenuation per mile at 12 and 18 GHz as a function of rain rate. It can be seen that for a given rain rate the attenuation in dB is roughly twice as large at 18 GHz as it is at 12 GHz. Other factors which enter into the calculations for rain-induced path fades include the probability of occurrence of a given rain rate and probable length of the rain cell. Another factor related to the rain attenuation is polarization. At 18 GHz where the rain attenuation is more severe it may be expected that vertically polarized microwave paths will suffer significantly less attenuation than horizontally polarized paths. The difference, although less than 20 percent could be of importance in marginal applications.

The probability of occurrence for a multipath fade is given by Barnett[2] as

$$P(L) = abfR^3L^2 \quad \text{for } R \geq R_{min}$$

where (a) and (b) are constants related to the terrain and humidity, f is frequency, R is range, and -20 logL is depth of fade. Thus at 18 GHz multipath fading can be expected occur 50 percent more than at 12 GHz. Moreover, the minimum path length, R_{min}, at which fading can occur is reduced by a factor of $f^{-1/3}$ according to Ruthroff's model.[4] Still, at 18 GHz, rain attenuation will be the predominant path reliability factor in most instances. Figure 3 shows the expected hours per year that path fade exceeds 20 dB as a function of path length. Three sets of curves compare predictions at 12.9 GHz with those at 18 GHz. The sets of curves correspond to most favorable, average, and most severe climate regions in the U.S. Figure 4 shows similar calculations for 30 dB

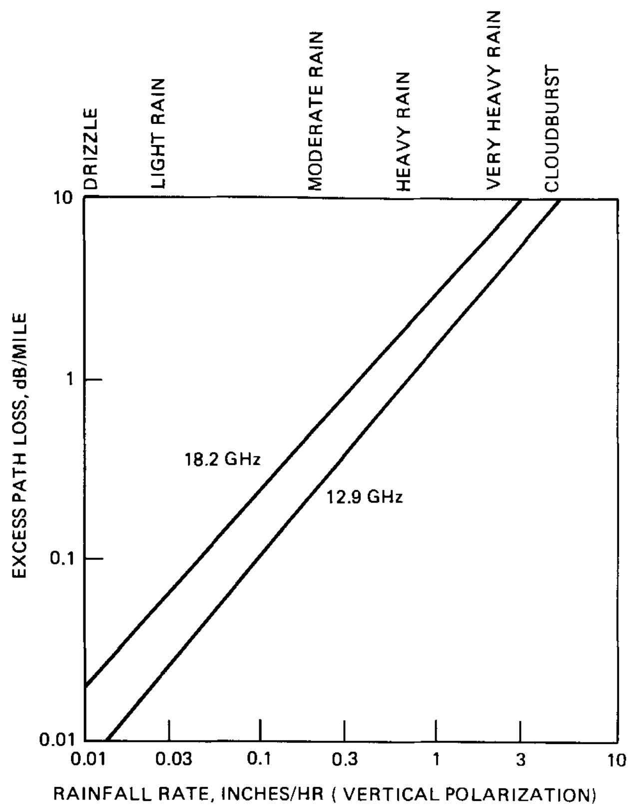

Figure 2 Attenuation vs rainfall rate.

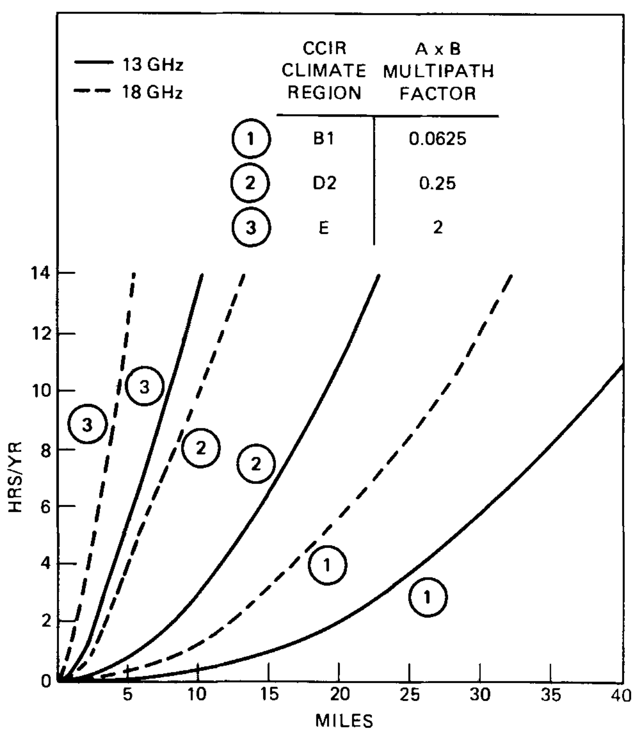

Figure 3 Path outage for 20 dB fade margin.

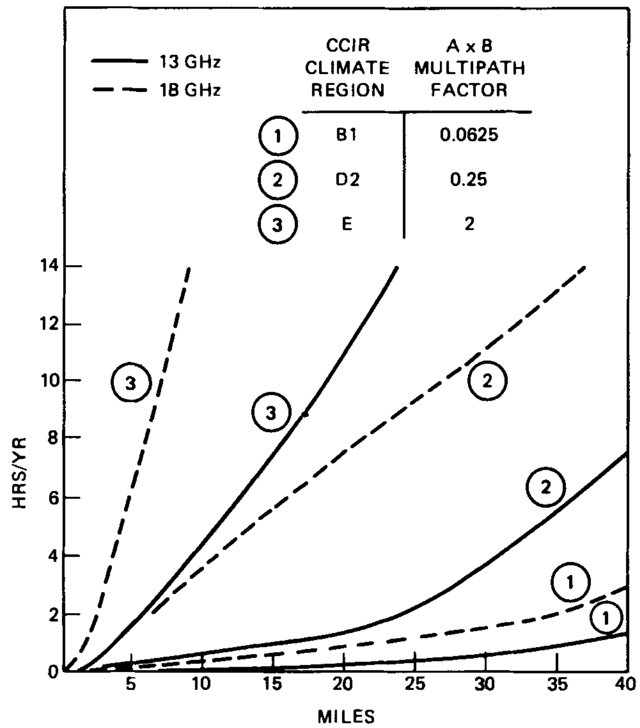

Figure 4 Path outage for 30 dB fade margin.

fade. Clearly, propagation limitations will play a bigger role at 18 GHz than at 12 GHz but substantial path lengths can still be achieved at 18 GHz if the equipment provides requisite performance.

HARDWARE DESCRIPTION

The preceding discussion shows that a higher system gain is needed in the 18 GHz band than in the 12 GHz CARS band to keep the system performance the same. Therefore, emphasis in the hardware development has been placed on the high power transmitter. Even matching CARS band equipment performance with similar performance at 18 GHz is however not an easy matter.

Figure 5 is the block diagram of an 18 GHz high power AML transmitter. A 5-cavity klystron has been specially developed for this application. It has the same type of package as the 12 GHz 4-cavity klystron and preserves almost all characteristics of the latter. Thanks to the improved gun design, the noise figure is even reduced by 3 dB. With this klystron, the transmitter can deliver over 10 W output power for FM application and 2 W for VSB-AM application. Very long service life can be expected because of the advanced cathode technology. Of course, operating at 18 GHz, a 3 kV beam voltage is necessary instead of the 2.2 kV required for 12 GHz. This causes 31 percent more dissipation than at 12 GHz, but the heatsink has enough capability to accommodate this additional dissipation.

The insertion loss of the channel filter goes up with the increasing frequency. At 18 GHz, it becomes a real problem. Although the low loss TE011 circular cylindrical cavity mode was used in the filter design, the actual insertion loss is 1 dB for 20 MHz bandwidth FM application and 4 dB for the 6 MHz bandwidth VSB-AM application. Therefore, the available power at the output of the 18 GHz transmitter is only 1 W for VSB-AM signals, even though the klystron actually delivers only slightly less power than the 12 GHz version. However, by using predistortion techniques,[5] the 18 GHz VSB-AM transmitter can easily deliver 2 W power at its output.

Phase noise is another problem of concern. Because of the higher frequency multiplication factor, it can be understood that the phase noise would increase by 2.8 dB if the other conditions were the same. Therefore, a low phase noise crystal oscillator and solid state source must be used in the 18 GHz equipment.

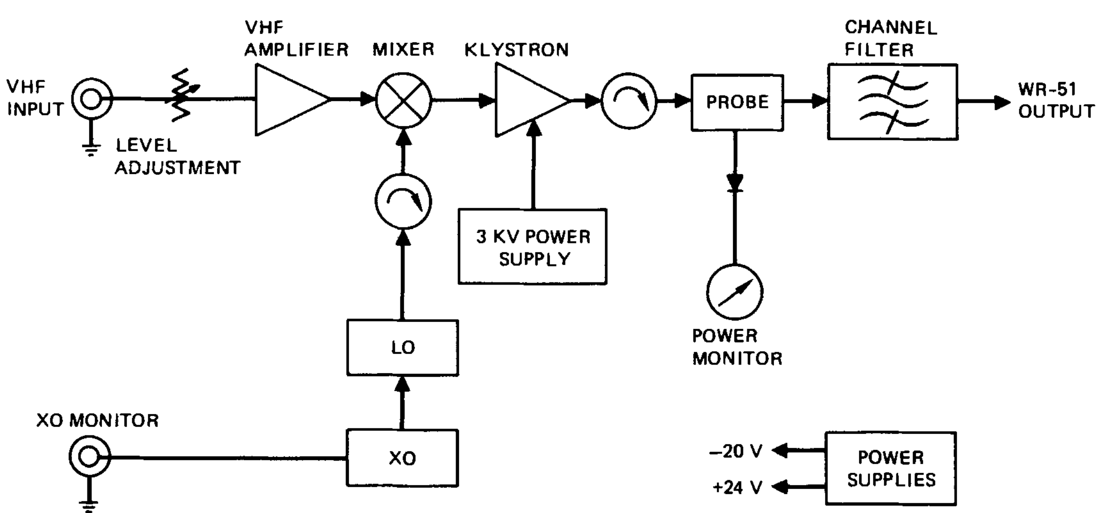

Figure 5 Block diagram of 18 GHz high power transmitter.

TABLE 1

TYPICAL PERFORMANCE PARAMETERS OF THE HIGH POWER VSB-AM TRANSMITTERS

Transmitter Parameters	18 GHz (No Predistortion)	18 GHz (With Predistortion)	12 GHz (No Predistortion)
Output Power, dBm	30	33	33
C/IM, dB	58	66	58
Freq. Response, dB	1	1	1
Diff. Gain, %	5	4	4
Diff. Phase, Degree	2	1.5	1.8

Table 1 summarizes the key performance parameters of the 18 GHz high power VSB-AM transmitters in comparison with the 12 GHz counterpart.

In contrast with the VSB-AM transmitter, the 18 GHz FM video transmitter can make full use of the klystron's capability. 40 dBm output can be easily obtained. 20 MHz wide channel allocation allows higher deviation and thus higher S/N improvement. Actually S/N of 68 dB has been achieved through an 18 GHz FM system. Moreover, the microwave transmitter-receiver link is almost "transparent" to the baseband parameters.

Besides the high power transmitters, an all solid state FM video transmitter with output of 20 dBm is also available. A GaAs FET amplifier is used in this transmitter in place of the klystron amplifier. The solid state transmitter may be suitable for short path length applications.

Two kinds of standard rigid rectangular waveguides, WR-51 and WR-42, can be used in 18 GHz systems. WR-51 was selected in the hardware design because of its lower attenuation at the frequency of interest. For WR-51 brass waveguide, the attenuation is about 0.1 dB/ft. at 18 GHz, while for WR-42, it is almost 0.2 dB/ft. By way of contrast, WR-75 waveguide loss at CARS band is only 0.5 dB/ft.

Circulators and magic tees are used for tranmitter channel multiplexing. Four high power transmitters can be mounted in a single rack. The circulator has an insertion loss of 0.3 - 0.4 dB, again almost double the loss of its CARS band equivalent. In a typical 4-channel circulator multiplex chain as much as 4 dB allowance must be made for the bottom transmitter. The magic tee has an insertion loss of 0.2 dB plus division loss of 3 dB. Considering the inevitable waveguide loss, two chains combined with a magic tee will suffer a loss of 3.5 dB. These values are also somewhat higher than in the 12 GHz system and must be considered in the link power budget. In addition, a transition to WR-42 is presently required to connect to available elliptical waveguide at 18 GHz. EW 180 guide loss is 5.9 dB/100 ft. vs 3.7 dB/100 ft. for EW 127 at CARS band.

The theoretical antenna gain increases as the square of the frequency. Table 2 lists the specified gain g and 1/2 power beamwidth for both 4 ft. and 6 ft. antennas at 12.9 GHz and 18.2 GHz. Although a 3 dB greater antenna gain is theoretically available at 18 GHz, the antenna surface tolerance must be held more tightly, while the beamwidth dictates that alignment and tower stability requirements are also tighter for a given size antenna diameter. Standard low cost antennas with diameter in excess of 6 feet are presently unavailable at 18 GHz.

The 18 GHz receiver design is similar to the standard CARS band AML receivers. Figure 6 shows the block diagram. Both the composite AGC and the phaselocked pilot tone AGC receivers are available. Because of the higher front end waveguide and ferrite attenuator loss and mixer conversion loss at 18 GHz, the receiver noise figure is 11 dB which is 1 dB worse than the CARS band AML receiver.

Two tone third order intercept point at the input of the receiver was measured to be 10.7 dBm. If the input carrier level is limited by AGC to -44 dBm for a C/N of 53 dB, the carrier to composite triple beat ratio C/CTB would be 80 dB for a 54 channel system, about as good as the CARS band receiver.

In case lower noise figure is required, a LNA and an image noise reject filter could be incorporated in the

TABLE 2

ANTENNA GAIN AND BEAMWIDTH COMPARISONS

Antenna Diameter (ft)	12.9 GHz		18.2 GHz	
	g (dB)	Φ_b (Degree)	g (dB)	Φ_b (Degree)
4	41.5	1.36	44.5	0.96
6	45.1	0.89	48.0	0.63

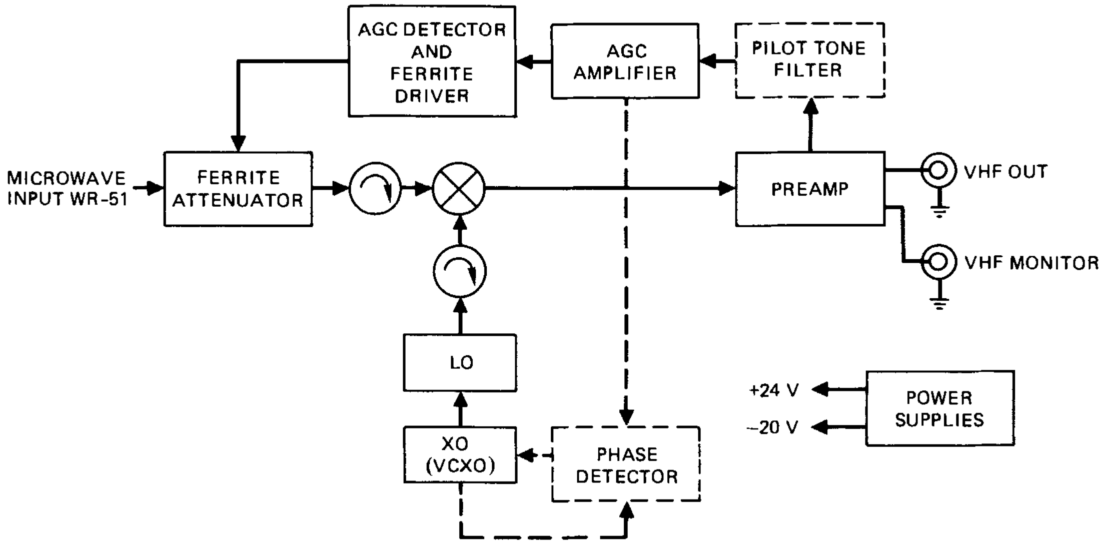

Figure 6 Block diagram of 18 GHz receiver (dashed line indicates phase-locked option)

receiver front end.[6] A receiver noise figure of 8 dB could be expected with a single stage LNA. Even lower noise figure would be achievable with a dual stage LNA.

PRACTICAL CATV APPLICATIONS

Some practical 18 GHz transmission systems have been evaluated for CATV applications.

The first example is a 32 channel LDS system with eight receiving sites in the Los Angeles area. The maximum path length is assumed to be 12 miles. Using 18 GHz high power transmitters with predistortion, 33 dBm/channel can be delivered at the output of each transmitter. The output circulator and magic tee multiplexing network losses then result in a minimum 18.5 dBm at each of the eight combined outputs. Table 3

TABLE 3

18 GHz AM PATH CALCULATIONS FOR TWELVE-MILE PATH IN LOS ANGELES

Transmitter Output Power (per channel after combining)			18.5 dBm
Transmitter Waveguide	50	Ft. Elliptical	-3.0 dB
Transmit Antenna	6	Ft.	48.0 dB
Free Space Attenuation	12.0	Miles	-143.4 dB
Receive Antenna	6	Ft.	48.0 dB
Receiver Waveguide	50	Ft. Elliptical	-3.0 dB
Atmospheric Absorption			-1.9 dB
Field Factor			-3.0 dB
Received Carrier			-39.7 dBm
Noise Per MHz			-114.0 dBm
4 MHz Correction			6.0 dB
Receiver Noise Figure			11.0 dB
Receiver Thermal Noise			-97.0 dBm
Receiver Carrier to Noise Ratio without AGC			57.3 dB

STATISTICAL ESTIMATES

MULTIPATH FACTOR (A x B) = 0.25
CCIR CLIMATE REGION = F

Hours Per Year Below 35 dB Carrier-to-Noise: Multipath	1.0
Hours Per Year Below 35 dB Carrier-to-Noise: Rain	2.8
Total Hours Per Year Below 35 dB Carrier-to-Noise	3.8
Percentage Reliability	99.956

TABLE 4

18 GHz FM PATH CALCULATIONS FOR EIGHTEEN-MILE PATH IN NEW YORK

Transmitter Output (per channel after combining)			32.5 dBm
Transmitter Waveguide	100	Ft. Elliptical	-5.9 dB
Transmit Antenna	6	Ft.	48.0 dB
Free Space Attenuation	18.0	Miles	-146.9 dB
Receive Antenna	6	Ft.	48.0 dB
Receiver Waveguide	100	Ft. Elliptical	-5.9 dB
Atmospheric Absorption			-2.9 dB
Field Factor			-3.0 dB
Received Carrier			-36.1 dBm
Threshold for 33 dB S/N			-78.0 dBm
Fade Margin to Threshold			41.9 dB

STATISTICAL ESTIMATES

MULTIPATH FACTOR (A x B) = 0.25
CCIR CLIMATE REGION = D2

Hours Per Year Below 35 dB Carrier-to-Noise: Multipath	0.04
Hours Per Year Below 35 dB Carrier-to-Noise: Rain	3.39
Total Hours Per Year Below Threshold	3.43
Percentage Reliability	99.961

summarizes the path calculation. The standard 3 dB field factor is included in the calculation to allow for small misalignment of various system components and miscellaneous losses which may otherwise not be accounted for. In this respect and also in the method of predicting hours below the 35 dB C/N quality level, the calculation copies the format utilized for CARS band LDS applications.

A second example is a FM microwave link for the transmission of 8 TV channels. The path length is 18 miles. 18 GHz high power FM video transmitters are used in this system. The calculation is similar to the first example, and Table 4 lists the results.

It is seen that for both examples the reliability is better than 99.95%. Thus, despite the negative impacts of increased propagation and equipment losses, reliable 18 GHz systems for CATV applications can be implemented. The developed 18 GHz AML equipment offers a viable solution of TV signal transmission for those areas where CARS band has already become overcrowded.

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TAC-TIMER

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ABSTRACT

Although most VCR's can be programmed to record at different times on different channels, the latter capability is lost when the VCR is preceded by a decoder. Channel selection must be done in the decoder and normally cannot be changed when the unit is unattended. The problem is eliminated with a new remote control transmitter. The unit controls the decoder with an IR stream using well-known techniques. Containing a real-time clock, it can be programmed to turn on the decoder, tune it to any channel and then turn it off at a specified time. Multiple events can be programmed, with a different channel for each. An event can be a specific time, as for a special, it can be a specific time once a week, for a series, it can be a specific time each weekday, as for soaps, or it can be a specific time seven days a week, as for the news. The time is displayed when the unit is not being programmed. In the programming mode, the display shows a series of prompts to assist the user. The unit also serves as a hand-held remote control.

THE PROBLEM

The normal configuration for a video cassette recorder (VCR), decoder, and television receiver in a cable system is as shown in Figure 1.

The decoder is tuned to any cable channel and provides a fixed-frequency output, typically channel 2, 3, or 4. For viewing or recording a channel, the receiver or VCR is tuned to the decoder output channel.

For unattended recording of a certain movie or special, the decoder is left on and tuned to the appropriate channel. The VCR is programmed to turn on, tune to the decoder output channel, and record during the designated time slot. This technique can be extended for taping several programs such as the news, a soap opera, or even several movies or specials, provided they are on a single channel; typical VCR's can be programmed to do repeat taping on a daily basis or to tape multiple events. As long as there is no power outage, which would leave the decoder off, the show(s) will be taped for later viewing by the subscriber.

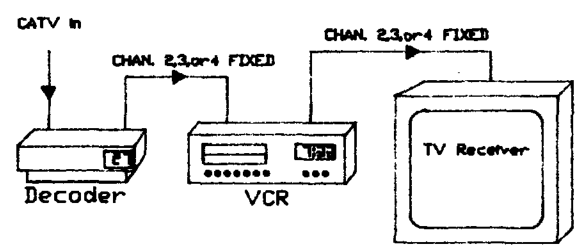

Figure 1 Connection for Decoder, VCR, and Receiver

A problem arises when the subscriber desires to record a program on one channel during a certain time and a program on another channel at a later time with no intervening attention. Although the VCR could be programmed to change channels at a certain time; that is of no use in this situation. Its input channel must still be the decoder output channel. The decoder tuner must select the different channels. If it has no mechanism for changing channels, the subscriber cannot use his VCR to record from multiple channels.

SOLUTIONS

To permit the subscriber to record from different channels, the decoder must in some way be instructed to change channels at specified times. Therefore, the unit which supplies the instructions must contain a real-time clock. It also must have memory to store the start and stop times and channel numbers. Two solutions are evident, as illustrated in Figure 2.

One solution, as in Figure 2(a), is to have the real-time clock and the memory reside in the decoder. Typically, this would be in a microcomputer which would also handle tuning, keyboard scan, display drive, and such. When the time-keeping and memory portions of the program indicate that a new channel is called for, it is a simple matter to branch to the tuning part of the program and tune the new channel.

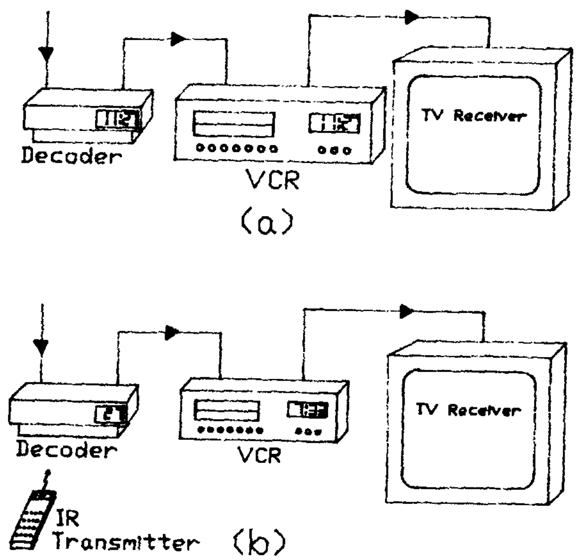

Figure 2 Solutions for the Decoder/VCR Problem

A second approach, as shown in Figure 2(b), has the clock and timing information memory built into an IR Transmitter. The transmitter determines when to turn the decoder on and off and when it is time to change channels. It sends commands to the decoder to cause it to respond appropriately.

With either of these solutions, the decoder can be left off, turned on at the proper time for recording, and then turned off again when recording is done. The user must understand that programming of either the decoder or the timer-transmitter does not remove the need to program the start and stop times into the VCR, as well.

TRANSMITTER APPROACH ADVANTAGES

The transmitter approach is probably the most economical for the parties concerned. This is arguable, depending on several factors, such as whether the cable operator supplies the unit with the built-in timer to all his customers or only to those who specifically request it. In the typical scenario, however, it is felt that the transmitter approach is less expensive.

The IR Transmitter approach also would be expected to have a shorter development cycle. This, too, is conjectural. It depends on the equipment manufacturer's resources, his existing tuning microcomputers and the ability to use left-over ROM or to upgrade to larger units and various other factors.

An unquestionable advantage of the transmitter approach is that it can be installed in a system with an existing decoder base without retrofitting boxes, provided those boxes work with IR transmitters. Thus, a manufacturer need not desert his early customers or force them to change out boxes to allow effective use of VCR's.

TRANSMITTER APPROACH DISADVANTAGES

There are certain disadvantages for the transmitter approach, as well. Some have workable means for minimizing the disadvantage.

The transmitter must be positioned so that its IR bit stream can be received by the decoder. The best solution for this problem is to explain it in the instruction manual. In programming and using the transmitter, the last step in the setup should be to position the transmitter and attempt to turn the decoder on, then off. Accomplishment of this task confirms a satisfactory IR path.

If functions such as "On/Off" and "A/B Cable Select" are toggle functions, it will be necessary to leave the decoder in a certain state, typically off, with A cable selected. This can be overcome, in some cases, by having separate "On", "Off", "A" and "B" functions, provided there are sufficient unused codes in the transmitter reportoire. With the functions separated, it is always possible to put the decoder into a certain state, regardless of its starting state.

A third disadvantage with the transmitter is the reliance on battery power. Although the timer-transmitter unit should require little more power than other transmitters, the consequences of low battery voltage are more serious. If the battery in a normal IR transmitter is low, the user simply uses set top controls until the battery has been replaced. When a timer-transmitter battery is low, the unit can lose memory or have insufficient output power to activate the IR receiver in the decoder. In either case, the user loses programming that he had wished to record, with resultant ill will. To minimize the low battery problem, one approach is to use a microcomputer with a sleep mode; the device uses little power most of the time, but occasionally it goes into the active mode to scan the keyboard, control the display, and such. A second approach is to provide batteries with capacity sufficient to power the unit for a long time, making the low-battery situation a rarity.

CIRCUIT

The transmitter circuit is shown in Figure 3.

The heart of the unit is a CMOS microcomputer. Two crystal oscillators drive the device. One runs at 32.768 KHz for the timekeeping application; it is very accurately adjusted via C3. The other oscillator, running at 3.2 MHz, steps the program counter; its accuracy is less critical.

At power-up, C9 and an internal pullup at Pin 14 combine to generate a reset for initializing the microcomputer. When the battery is removed, CR4 allows C9 to power the microcomputer until discharged. This relatively quick discharge of C9 guarantees that a reset will be generated and the microcomputer initialized when a new battery is installed.

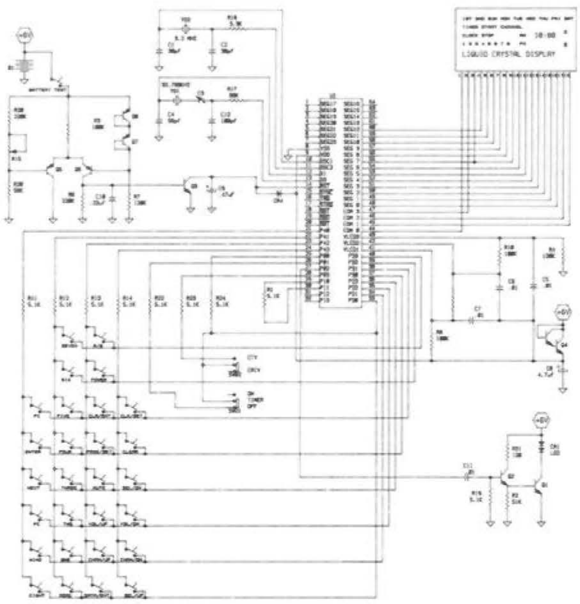

Figure 3 IR Timer-Transmitter Circuit

Because it is so important that programming not be lost, a battery test circuit is provided. Q5 and Q6 comprise a differential amplifier. Q5 is biased by a resistive divider from VDD while Q6 is biased by diodes (Q7, Q8) and a resistor. The voltage at Q6 base drops more rapidly as battery voltage falls. As a result, when the battery voltage drops to a level predetermined by the setting of R15, Q3 discharges C9, resetting the microcomputer. The need for a fresh battery is indicated by the display, which shows dashes in the time display. The test circuit is connected to the supply through a button on the keyboard, drawing power only during an actual battery test.

The microcomputer scans the keyboard for key closures. It also monitors switch positions for the two slide switches that put the unit into the timer mode and indicate whether the IR bit stream should be configured to control the decoder or the television receiver.

A liquid-crystal display is driven by the microcomputer. During a programming operation, the display shows a series of prompts for the operator. When not being programmed, the unit shows the time of day. The display has a wearout mechanism when driven by DC. Accordingly, it is supplied with stairstep voltage waveforms generated by switching various reference voltages. These voltages are generated in a divider comprised of R4, R8, R9, R10, C5, C6, and C7.

The output of the transmitter is a coded IR signal generated by CR1. The IR emission is switched on and off by Q1, Q2 according to the signal from Pin 27 of the microcomputer.

PROGRAMMING

Figure 4 shows the transmitter keyboard, switches, and display. Most of the keys appear on a conventional remote control transmitter, Keys added for programming are "Next," "Program Set," "Clock Set," "Select Up," "Select Down" and "Clear."

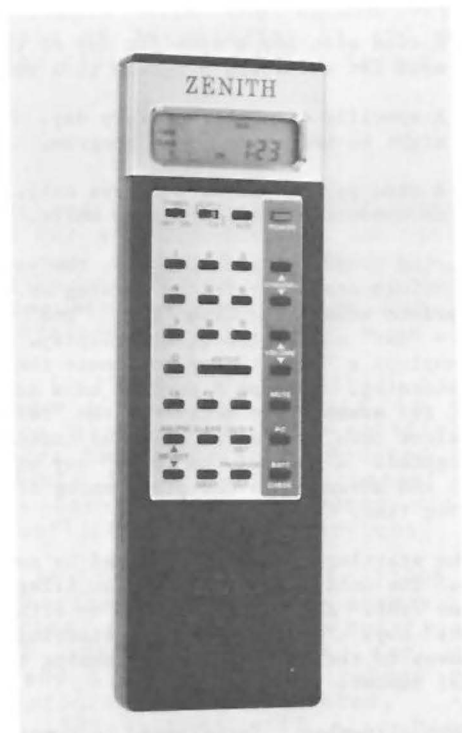

Figure 4 the Timer-Transmitter

Setting the Time

To set the time, the user pushes "Clock Set." The day of the week is indicated at the top of the display. Either "Select" key is used to correct the day, if necessary. When "Next" is pushed, the unit is ready for the time to be programmed. The time is entered by the numeric keys. AM/PM is specified with either "Select" key. With the proper time displayed, "Next" is pushed, starting the clock and stepping the unit out of the time-setting mode.

Programming for Decoder Control

The programming mode is entered by a push of the "Program Set" key. At that time, one of eight event numbers in the lower left part of the display flashes. This number is for the lowest-numbered vacant event. The user may program that event or use a "Select" key to go to a different event. In any case, the data programmed will overwrite whatever data had been in the memory for that event. To indicate that the event number display is the one to be programmed, the user pushes "Next."

The next item to be programmed is the day(s) for the event to be recorded. An event can be defined as:

- o A time period on a certain day of either the first or second week. This would be used for a movie or a special.
- o A time slot for a specific day of the week, used for recording programs in a series.
- o A specific time period every day. This might be used for a news program.
- o A time period during weekdays only. This accommodates the soap opera buffs.

During programming of the day, the various combinations are indicated by turning on an appropriate selection from "1st," "2nd" and "Sun" - "Sat" at the top of the display. The user employs a "Select" key to choose the day(s) for recording. To tape a program on a daily basis, for example, he activates the "Select Up" or "Select Down" key until all nine indicators are lighted. A push of the "Next" key stores the day(s) and advances to the programming of starting time.

The starting time is programmed by numeric entry. The unit will not accept an illegal time such as 7:86. AM or PM is chosen by either "Select" key. "Next" stores the starting time and moves to the next step, programming the channel number.

Channel number is programmed by numeric entry. The unit will not accept an illegal channel number such as 282. If the system has dual-cable with A/B indicators, A or B is specified, using the A/B key. "Next" stores the channel number and steps to the programming of the stop time.

The time to stop recording or turn off the decoder is specified by numeric entry. Illegal times are not accepted. AM and PM are chosen by either "Select" key. "Next" stores the stop time and the unit exits from the programming mode. If the user has inadvertently programmed the same start and stop times, the unit flashes the event number. If this is ignored, the times are treated as correct entries, that is, it is assumed the user desires to tape for 24 hours.

To clear the memory for an event, the steps are:

1. Push "Program Set."
2. Specify the event to be cleared by using either "Select" key.
3. Push "Clear."

This clears that event memory and takes the unit out of the programming mode.

REVIEWING

To review the data programmed for an event, the user presses "Program Set" and then "Select" to choose the event to be reviewed. He then presses "Program Set" to step through and verify each piece of data programmed. Three more pushes of "Program Set" allow the user to verify the day(s), start time, channel number, and stop time. The last push returns the unit to the clock mode.

OPERATION

Following programming, the user places the "Timer On/Off" switch in the "On" position, which is for attended control of the decoder. He places the unit so that it has a clear line of sight to the decoder and verifies this by operating the "Power" switch to turn the decoder on. He makes sure the unit is on "A" cable, for a dual-cable system and then switches the decoder off. The first event scheduled after the "Timer On/Off" switch is placed into the "On" position starts the two-week timing cycle. At the end of the cycle, it starts over and repeats continuously until the "Timer On/Off" switch is placed at "Off."

The transmitter can be used as a normal decoder remote control, even while in the "Timer On" mode. With the "CATV/TV" switch in the "TV" position, it will also control television receivers made by the same manufacturer.

SUMMARY

The timer-transmitter is a unit that the operator can purchase for use with his existing decoders. It is reasonably easy to program and allows the user to optimize the use of a VCR on his cable system. For these reasons, it should have a substantial appeal to the cable operator for revenue enhancement.

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TESTING AND LINK ANALYSIS OF MULTICHANNEL TELEVISION SOUND

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ABSTRACT

The transmission of Multichannel Television Sound (MTS) is a reality; over 200 stations are now operational in the stereo mode. The technical effect of carrying the MTS signal over cable television systems is not yet clearly understood. In order to understand what effect our systems have on carriage of MTS, a testing program was designed and implemented using link analysis. This testing program included each system component from the broadcaster's master control, through to the end of a cable cascade. This presentation will document the measured results of that testing, and method used.

INTRODUCTION

Since the advent of Multichannel Television Sound, a number of articles have been published describing ways to test and evaluate the MTS signal. Testing this complex waveform and understanding the effect the MTS technology will have on the cable television industry is very difficult, at best. Understanding the operational impact to the systems so that business and marketing plans can be implemented, is the present challenge.

The purpose of this paper is to outline the test methods used to evaluate the MTS signal, and present the measured results of testing on an operational system.

DESCRIPTION OF THE MTS BTSC SYSTEM

The delivery of MTS uses the system recommended by the Broadcast Television Systems Committee (BTSC). This audio delivery system allows stereo to be added to the existing television system. By comparison, the BTSC system is similar to the FM broadcast system now in use. There is, however, one major difference. A companding system is incorporated in the (L-R) channel. This companding system is used to improve the signal-to-noise ratio of the stereo system.

The main channel aural-carrier audio modulaton consists of an (L+R) signal that is subject to a 75us pre-emphasis. The subchannel (L-R) signal is subject to the effect of compression at the encoder or transmitter part of the system, and a complementary expansion occurs at the decoder or receiver part of the system. The compressed (L-R) signal double-sideband, suppressed-carrier amplitude modulation of a subcarrier at 2fh, where fh is the transmitted video horizontal scanning frequency of 15.734 KHz.

The main channel (L+R) peak deviation is ±25 KHz. The stereo subchannel (L-R) and the main channel (L+R) have a peak deviation of ±50 KHz when full interleaving with (L-R) channel is compressed. The stereo pilot subchannel has a peak deviation of ±5 KHz. Also, included in the BTSC system is a Second Audio Program channel (SAP) at 5fh. The peak deviation for the SAP subchannel is ±10 KHz. The Professional Channel is at 6.5fh at a peak deviation of ±3 KHz. The total deviation sum is 73 KHz.

The SAP channel uses the BTSC companding system. The Professional Channel uses 150us pre-emphasis.

THE EFFECT OF COMPANDING

The effect of companding on the (L-R) stereo channel and the ability of the decoder to rack the encoder are the main difficulties in testing and using the system. If the companding in the (L-R) subchannel does not track the 75us pre-emphasis in the (L+R) main channel, a host of measuring and operating problems are encountered. The BTSC recognized this problem when they set their recommended specifications, published in report OST-60. Those specifications acknowledge that at certain frequencies, stereo separation and other parameters would be degraded. In order to maintain a high degree of quality to our subscribers, accurate level setting and phase adjustment are a must.

75us EQUIVALENT MODE

It is possible to remove the companding system during testing. By inserting a 75us pre-emphasis network in the (L-R) channel at the encoder, and also inserting a 75us de-emphasis network in the decoder receiver, this, in effect, bypasses the companding system in the (L-R) stereo subchannel. The bypass of the companding system allows the system to be linear throughout, much like the conventional FM broadcast system. Using this equivalent mode allows all parts of the system, including the link, to be tested accurately with exception of the companding system, i.e., compressor and expander. Most manufacturers of broadcast encoders have this 75us equivalent mode built in. The only decoders being built with this mode are modulation monitors. Their cost is very high for cable applications.

MURPHY'S LAW

At this point in the paper, I had planned to present the method and measurement. As all good engineers know, our best friend Murphy can sometimes spoil the plan. After six attempts, working the after midnight sign off shift, we found a number of problems with the testing that could not be overcome in time for this paper to meet the January 15 deadline to the printer.

Test equipment is one of the key factors that need to be addressed in order to overcome the problem. The other is a broadcast encoder that performs well in the BTSC mode. With support from the manufacturers of encoders and decoders, and the support from broadcasters and test equipment vendors, we can solve the problems of carrying MTS on our systems. On completion of the testing, I will add the results to this paper, hopefully in time for the presentation in March.

Anyone desiring more information can call me at ATC (303) 799-1200 ext. 709.

THE BRITISH TELECOM SWITCHED STAR SYSTEM IN WESTMINSTER
PART 2: INSTALLING THE SYSTEM

John Powter - Project Controller, Westminster

BRITISH TELECOM

ABSTRACT

Westminster was one of the first eleven pilot franchises advertised in August 1983. The franchise was awarded to Westminster Cable Company who named British Telecom as the cable provider. The system was to be a switched star network, with potential for a comprehensive range of interactive services. The licence to run the system was awarded jointly to Westminster Cable Company and Broadband Ventures Limited (a wholly owned subsidiary of BT) in April 1985 and contruction commenced immediately. Service to trial customers was started in June, and commercial operation began in October.

INTRODUCTION

In part 1 of this paper Kevin Shergold has briefly described the switched star network, and you will see that its basic design has not changed since I gave a paper on the subject at this Convention some two years ago. The system uses brand new technology without equal on a commercial scale anywhere in the world. The main build has been underway now for six months so this paper describes early operating experience and gives some of the features of the administration system.

THE FRANCHISE AREA

Westminster was established as a unit of local government for the area in 1963 by the London Government Act. The Act effected a merger of the former London Boroughs of Westminster, Marylebone and Paddington into a single administrative and representative local government unit. According to the 1981 census returns the resident population is 163,892 with 73,132 private households, of which about 40% are housed in apartment blocks. Additionally there are some 22,000 commercial premises (offices, shops, banks, etc.) and over 500 hotels providing around 60,000 bed spaces. During the day Westminster accommodates half of Central London's workforce (half a million workers) yet two thirds of the resident working population work within the Borough. Westminster also contains 60% of Central London's shopping floor space.

The franchised area follows exactly the boundary of Westminster Borough, stretching from our seat of government, the Houses of Parliament, in the south to the residential suburbs of St John's Wood and Maida Vale in the north.

THE CABLE PROVIDER AND CABLE OPERATOR

Within the UK a distinction is drawn between the cable operator and cable provider, although there is no legal obstacle to these being the same organisation. In the case of Westminster, British Telecom, through its wholly owned subsidiary, Broadband Ventures Limited, is responsible for planning, installing and maintaining the system. BT also finances the network. Westminster Cable Company (in which BT has a 20% stake) is the licenced cable operator, and as such is responsible for negotiations with programme and other service providers, and marketing the cable service to potential customers. The system is owned by BT and capacity on the network is leased by BVL to the operator. It is important to remember this split in responsibilities when the facilities of the System Administration Centre are described later.

NETWORK PLANNING

Over 90% of the existing telephony plant in the franchise area is underground, and additionally a large part of the franchise has been designated a Conservation Area, to which special rules concerning the siting of external plant apply. There was no way that the local authority would agree to the siting of overhead wires for the delivery of cable tv, so the network was planned in the same way as the telephony plant, only going overhead where the existing plant was so arranged. Consequently the network mimics that which is in use for telephony, with the head end feeding out to hubsites and thence to the wideband switches. A total of eight hubsites will be established within the area, all co-located with existing telephony central offices. Existing tunnels and surface duct routes are used for the head end to hubsite links, as the space taken by these optical super primary cables could be found. An 80 fibre cable is about 5/8 of an inch in diameter. A small amount of new duct has had to be laid for the primary network, mainly from the switch position to the nearest main duct route. Here again the small diameter of the optical fibre cable helps. However, from switch to subscriber, where small bore coaxial cables are used, almost all new duct has had to be provided.

Ten 30-tube coaxial cables run away from each switch, occupying four 4 inch duct bores, and these are split down to 20 and 10 tube cables. Each 10 tube cable terminates in a distribution point housed in a footway joint box. These cables are installed before a switch is released for marketing so when a customer agrees to subscribe his "drop cable" is installed and connected. Unfortunately many of these "drop" cables require new service pipes (a one inch diameter duct running from footway to house) to be run, and this inevitably means on site discussions with the home owner. Consequently we can only offer a 21 day installation from the time that the subscriber agrees to take the service.

At the present time all the cabling plans are drawn by hand, but it is intended in the near future to change to a computer based system. Large scale digitised maps of the franchise area have been recently made available, and the interactive graphics terminals and software are already installed. This facility will ease the time consuming job of drawing up plans and producing works estimates and parts lists. Another planning aid has been developed for areas where digitised maps do not exist. Large scale maps are photographed and laid down onto video disc. A personal computer controls access to the disc, and holds the plant information as a computer generated overlay. Both systems have the planning rules built in, and can generate works estimates and a list of parts.

CABLING AND JOINTING

Both the optical fibre and copper coaxial cables have been designed and specially made for this network. New jointing techniques and joint closures have been devised. The multimode optical cables are of loose tube construction with ten fibres in each tube. The tubes are layered round a polyethylene insulated central steel strength member and the outer polyethylene sheath has an aluminium moisture barrier. At a joint each tube of ten fibres is split down into individual fibres, each sleeved with small bore PTFE tubing. The transition between the hard arnite of the loose tube and the individual PTFE sheathed fibres is achieved by a small flexible moulded manifold. Although this may seem to be an awkward job, experience has shown that the task is easily achieved, but it does call for good eyesight and a steady hand. Individual fibres are fusion spliced, and the bare fibre and completed splice are enclosed in a splice protector, consisting of a metal bar and a meltable adhesive liner inside a heat shrinkable sleeve. Splices and excess fibre (to allow for rejointing) are assembled into metal trays, which are in turn put in a chassis, and the whole enclosed in the joint closure. When optical tapping is needed, the splitters are also mounted on the trays within the joint.

The primary and super primary cables are pressurised with dry air, and pressure monitors are mounted on each joint. The status of these monitors is continually checked using a microprocessor based system at the head end, communicating with each monitor over the metallic strength member and aluminium moisture barrier in the cable.

Optical fibre tail cables are used to connect equipment to the route cable. These are tight jacketed fibre, and where they are run internally, for instance at the hub sites, can have up to 80 fibres. Air blocks are incorporated in the joint where this cable is connected to the loose tube route cable. Pre-connectered ruggedised tail cables are also used to interface to the optical equipment either at the switches or the hubsites. Installation experience so far has been most encouraging. Where circumstances permit lengths of over one kilometer can be pulled in. The average joint loss is under 1/2dB, although there have been some instances of losses over 1dB which have defied all attempts to lower them by remaking the joint. These seem to occur in areas of high humidity, for example in cable tunnels. The increase in loss is not significant, as the fibre loss of the

cable is below its design specification, to which the network was planned. Cables are tested before the joints are finally closed, and this has revealed that a number of the optical splitters have been faulty. Once these have been replaced, and the joints closed, there have, to date been no optical cable faults.
The coaxial cables used in the secondary network are, like the fibre cables, available in two main types. The route cable, in 10, 20, or 30 tube sizes which has a tape outer conductor, and the terminating or tail cable which is of braided construction. This is more flexible than the tape cable, and each tube is separately covered with a thin polyethylene layer, allowing direct termination on an F type connector. Pre-terminated 30 tube tails are available to connect to the switch. Special tools are used to strip back the inner and outer conductors, and splices are made using an infra red heat gun and pre-formed solder filled parts, one to join the inner conductor, and the other, contained in heat shrinkable tubing, to join the outers.

The splices are tested before the joint is closed, and the percentage of bad joints has been small, and mainly due to operator error, for example poor stripping of the outer insulation (paper) on route cables.

There is, under development, a crimp splice, which will offer time savings. The development has been hampered by a particular cable which was manufactured with an overall diameter just over the specification, such that the crimp would not perform correctly.

This secondary network, once commissioned, has also been fault free. There have been a very small number of faults on the customer drop, all due to badly fitted F type connectors. It is a feature of the customer signalling system that a direct current path must exist between customer unit and switch, so a faulty connector usually results in the customer not being able to change channels. This has the advantage that the fault is immediately reported and repaired, so preserving the integrity of the screening on the secondary network.

SYSTEM ADMINISTRATION AND MANAGEMENT

The system is controlled by a suite of computers at the head end. These communicate with the switches by data links carried on the optical network, and to terminals at the cable operators and providers premises. There are two main subsystems, and a number of secondary subsystems dependant on the amount of interactive facilities required. The subsystems communicate via an Ethernet bus.

The main subsystems are:
-- Administration, providing facilities for
- Homes passed database
- Secondary network plant and DP records
- Customer account maintenance
- Billing for subscription tv, pay per view, videotex, video library
- Sales ledger accounting
- Automatic payment methods
- Works order processing
- Master control of distributed databases
- Special features

--Management subsystem
- Network configuration
- System initialisation
- Fault and error control
- Data collection from customers
- Real time control of switch (class of service records etc.)
- Pay per view programme control
- Primary network plant database

The secondary subsystems installed in Westminster are:

Information server, providing 1000 pages of rapidly accessable videotex information, and carrying at the moment a programme guide to all channels, a local news service, community information from Westminster council, and a guide to the use of the system. Additionally this server can be used to customise the first videotex page as seen by a customer on a particular switch, and direct him to particular areas of the database. A large hotel is using this facility at the moment.

Videotex server, providing many thousands of information pages, and may be likened to the public Prestel videotex service. Unlike the information server, the customer can be charged for the use of this server. It is important to remember that the subscriber needs no extra equipment in his home to receive these services. The text information is sent as a data stream to the switch, where text generators turn it into video information for reception on a standard tv set.

Traffic subsystem, keeping a record of processor occupancy and traffic levels on the system. An invaluable tool for the design and dimensioning of future networks, and predicting when to relieve the current network. (The design is such that processor overload can be relieved by connecting additional processors to the Ethernet)

Video library subsystem, providing on demand access to material held on video disc. As this is a one to one service the customer can, from his keypad, control the functions of the player. Examples are stop, start, slow, search to a frame etc.

Photovideotex subsystem, produces video output of photographic images stored the processor. This can be used in conjunction with the videotex and library subsystems to insert photographic quality images into videotex pages.

Gateway subsystem, providing interfaces to other databases,such as Prestel, electronic mail, etc.

These last three subsystems, although installed, have not yet been commissioned. Their functions have been demonstrated on the experimental switched star system installed in the Research Laboratories at Martlesham Heath.

CONNECTING CUSTOMERS

To illustrate the use of the management system it will be useful to describe the stages passed through in connecting a customer. The basic data loaded into the system at start up was an address file, obtained from the postal authority and containing all known tenancies with postcode, but without names. The network planners then defined switch areas, and associated switch numbers to groups of tenancies. Detailed planning of each switch area was then done, and the network details entered into the database. Consequently the network manager knows, and can identify, which tube runs from the switch to a particular distribution point, and which addresses are served from that point. This data entry is manual at present, but the link between the graphical planning aid mentioned earlier has been tested and is about to be commissioned. The switch is then installed along with the cabling, and then that area is "ready to connect customers".

At this time the operator can begin marketing and creates in the administration machine an account file of signed customers. At the same time programme options for each customer are entered. Having created an account the system checks to see that there is a network resource available, and if so, allocates this to the customer. The class of service information is downloaded to the local processor in the switch and the system then asks for an appointment date. This is entered, and provided that manpower is available, the appointment can be confirmed. The manpower diary has been previously populated with available manhours by the providers installation control. The system then creates a work order, showing all information needed to connect the customer, including any special comments made by the operator. This work order is not issued until just before the installation date, but summaries of all pending orders are continually available, and these are checked by the installation planners for availability of service pipe etc.
If for any reason a network resource cannot be allocated, then a planning work order is issued immediately for remedial action to be taken, and the operator is prevented from making an appointment. This may occur, for example, where difficulty has been found in obtaining wayleaves, or the switch needs upgrading to serve more customers.(The switch is not fully populated to start with). When the planning work has been cleared the operator is free to make an appointment. The work order is issued to the fitter who completes the installation by patching the switch outlet to the customers tube in accordance with the instructions on the order, drawing in and connecting the drop cable, installing the customer unit, tuning the tv to the cable output channels, and demonstrating the facilities to the customer. He also checks that the right tube has been connected by entering a test sequence from the customer's keypad, which returns the customer account number from the switch, and this is cross checked with the account number on the work order. The fitter can write any comments on the order, and the customer is asked to sign to the effect that the work was carried out to his satisfaction. On return to installation control any further comments on the order are entered into the system, as is the time taken for the job, and any additional chargeable items. At this point the order is closed as far as the provider is concerned, and it is from this time that the provider starts to charge the operator the lease charge for that particular customer. The completed order is placed in a history file for subsequent analysis, and reports are available to the installation manager regarding proportion of jobs completed within standard hours etc.

The system passes details of closed works orders to the provider, who in turn has to log them off the system, it is from this time that the customer billing cycle begins.

CUSTOMER BILLING

The billing system has to collate not only the monthly subscription charges, but also session charges. The system can allow the subscriber to authorise himself, from his keypad, to watch pay per view programmes, or to change his service tiers (self spin). Videotex and library access can also be charged on a per session basis, and if these services are available to hotels the charges must be immediately available. Consequently the billing system works in real time, with session charges being added as they occur.

On receipt of payment the system allocates the cash, monitors payment performance and performs credit control on delinquent customers. The operator can, of course, switch off or reduce the service to bad payers from his terminals. The final stage is to issue a recovery work order to the provider. It is possible using the facilities of the information server for a customer to call up and view his current charges, and it is an extension of this facility which allows hotel management to charge their guests for session based services. The billing system also records credit due to programme providers.

Many of the more advanced facilities, self authorisation etc., although implemented have not yet been activated. The average subscriber has not been exposed to cable before, so he will not be able to understand all the sophisticated facilities available to him. Furthermore, the addition of these facilities will have ramifications on the marketing strategy of the operator.

FAULT MONOTORING AND REPORTING

The system includes comprehensive monitoring facilities. At the switch the incoming optical power is continuosly checked, as is the temperature and humidity within the cabinet. Cabinet door openings are also logged. At the head end and hubsites the laser current is monitored, as a rise here is indicative of a failing laser. All these alarms are collated by the system manager and displayed on a terminal screen. The trigger points on the optical components are set such that an alarm is given before service is affected. By analysing the pattern of these alarms, in conjunction with the output from the air pressurisation monitoring system, serious cable breaks can be rapidly detected. Each switch has, as well as fibres feeding signals to it, one fibre which is used for signals in the reverse direction. Part of the capacity is used for control and data traffic, but there remains capacity for four upstream tv channels. It is intended that one of these channels is used for monitoring purposes, so that outputs from sub switch units can be fed back to the head end and checked.

The one part of the network that is not monitored is the subscriber feed. A pilot does exist on this link, it is used by the customer unit for automatic gain control and equalisation, and serious consideration was given to monitoring the level of this pilot over the secondary link data connection. This was abandoned on the grounds that the system would not know whether a fault existed, or whether the customer had just switched his box off.

When a customer experiences a fault, his interface is with the cable operator, who is aware off any major network faults. If this is an isolated incident, the operator takes the customer through a simple question and answer routine to try an pinpoint the problem. Questions such as "Does the red light on the set top box flash when you press a key on your keypad?" check whether the customer signalling system is working, and "Have you got a picture on your other cable channel?" check whether the transmission link is in order. (Each subscriber can have two simultaneous switched channels, as well as FM radio). If the fault cannot be cleared in this way, then a fault work order is produced by the system and immediately printed in the provider's maintenance control. Records of these works orders are kept for analysis.
The software system itself incorporates many checks for errors. It reports failed attempts at sending messages amongst its subsystems. It is continually monitoring the state of the processors in all switches and causes immediate alarms should it detect anything amiss. It also checks the database in each switch against its own master copy. Facilities are provided so that the maintenance control engineer can manually look at the switch database either from the central maintenance control position, or by means of a small hand held terminal which plugs into the maintenance port at each switch site.

An important consideration in the design of the software was that it should allow the system to fail gracefully, and attempt to preserve at least some service to subscribers. Thus a fault in any of the secondary servers only causes the loss of that service, and a fault in either the administration or manager subsystems, although serious, does not cause catastrophic failure of the total system. Instead the switches go into isolation mode, with their local processor carrying out all normal functions. During this time no changes can be made to individual customer"s class of service records, and the services provided by the head end are unavailable (information, videotex etc.) but accounting information is stored until the head end comes back. This philosophy is taken further in that if the switch processor fails, channel switching of "free" and "subscription" services is done by the microprocessor on each sub switch. Only if this micro fails is service lost to thirty subscribers, and provided that the rest of the system is in good health, this will be reported immediately to the maintenance control.

RELIABILITY

The customer base and network size is as yet too small to get any meaningful figures on reliability, however some observations can be made. As has already been mentioned the number of cable faults when commissioned is zero. The same can not be said of the optical transmitters, where in the early days there was an almost 25% failure in lasers. This is still the subject of intensive investigation, but has been isolated to an early batch by one particular manufacturer. During system development lasers from the same manufacturer showed excellent life test results. Happily, later laser cards do not exhibit such a failure rate, as of some 150 cards on pre-commissioning soak test only two have failed. It is also gratifying to know that of the early failures all were trapped by the rising laser current monitor before they became service affecting.

Early difficulty was experienced with connectors on the launch module cards.(The launch module takes the signals from the sub switch unit and sends them down the subscriber coaxial cable). A faulty batch had been supplied by a manufacturer, such that when the patch cord was tightened it destroyed the connector. Measurements proved that the connector was not meeting its specified tightening torque.

Trouble was experienced with the low noise amplifiers on the satellite antennas. They exhibited a peculiar oscillation mode when the temperature fell below freezing. This has been confirmed by the manufacturer and a different design of l.n.a. has been installed. Generally the satellite receivers have been a source of annoyance, as they seem to need almost constant fine tuning to preserve picture quality. Unfortunateley the uplinked signal cannot always be relied on to be perfect, nor can the signals being broadcast from terrestial transmitters. The switches have so far proved very reliable, as have the customer units. The worst record is that of the hand held keypad and associated infra red receiver, this is being investigated. A large proportion of the reported faults can be shown to be customer error, often detuning of their television receiver or experiencing difficulty in using a video recorder. This has pointed to short comings in the user guide supplied to the customer, and this is being revised. It must also be said that in the early days the cable operator's staff were not totally familiar with the system and this led to a higher proportion of perceived faults being reported to the provider, instead of being cleared by talking to the customer.

There have been annoying bugs in the software, but none which have caused a complete shutdown. The software has been amended as a result of discussions between operator and provider to fit in with procedures designed to ensure trouble free installation and operation. It has, at times, been difficult to persuade people to use the system as intended, as it as seen as reducing their freedom for manoeuvre. Training both parties in the use of the system had been underestimated.

The worth of the "gracefull fail" has been amply demonstrated on a number of occasions when the computers have stopped due to a small glitch in the mains power supply. These normally result in no complaints from customer's, but one from the operator who cannot use his terminals. It was mistakenly assumed from records of the reliability of the mains supply that no standby power need be provided. However the machines are very sensitive to even a half cycle interruption, so steps are being taken to provide an uninterruptable supply with a 15 minute backup capacity.

CONCLUSION

The system commenced its trial phase in June of 1985 with 200 customers connected to two switches. By October confidence in the system design and fault rate was such that the operator commenced commercial operation and the provider began installing more switches. At the end of 1985 16 switches were operational. Experience shows that this switched system works, and works reliably.

ACKNOWLEDGEMENTS

Many people have contributed to this project since its inception five years ago. The hardware and software design was done by Research Department, external plant and cable by Local Line Services, installation by the staff of Local Communication Services. All have been dedicated to the success of this system. The cable operator has worked with us with a spirit of cooperation, and Broadband Services has had sufficient vision to back new technology.

THE BRITISH TELECOM SWITCHED STAR SYSTEM IN WESTMINSTER (LONDON) UK
PART 1: AN ADVANCED SYSTEM

Kevin Shergold
Director of Local Line Services

BRITISH TELECOMMUNICATIONS PLC

INTRODUCTION

During the last three or four years, Cable Television Operators in the USA have been quite justifiably cynical about the prospects for advanced Cable TV Systems which offer a sophisticated range of interactive services using optical fibre technology and off-premises switched electronics:

- There is still little evidence in the USA of a significant market place for interactive services.

- Coaxial technology is a safe and secure technology that is now well understood by the Industry.

- Above all, the cost of coaxial plant is still significantly cheaper than systems which employ optical fibre and switched technology.

In the UK however, the political, regulatory and commercial climate is very different to that of the USA and this has directed the British Communications Industry down a path which has resulted in the painful birth of a somewhat fragile Cable Television Industry.

In spite of all the difficulties and setbacks, most of which were out of British Telecom's control, the Switched Star System is now operational in Central London and is proving to be a strategically important element in the introduction of optical fibre into the Local Communications Network.

The commitment towards the use of fibre in the local network by many of the Telephone Operating Companies throughout the world will bring down the cost of fibre and optoelectronic devices and challenge MSOs on the use of these new technologies. During the next decade, the telecommunications industry will be moving towards the provision of integrated broadband local networks capable of delivering not only entertainment television and information services but also general telecommunication services including telephony.

The Switched Star System has been developed in British Telecom's Research Laboratories with particular focus on the entertainment television and information services aspects BUT with the clear intent to evolve towards all digital, all fibre integrated services.

This paper (Part 1), together with Part 2 by my colleague John Powter will outline the political/regulatory background in the UK, describe the Switched Star System and its construction in the densely populated urban community in Central London and briefly discuss the economics and marketing prospects.

BACKGROUND

Most observers of the European Cable TV scene are agreed that there has been a dramatic turnaround over the last few years and this has been particularly visible in the UK. The early enthusiasm generated by the publication of the Information Technology Advisory Panel Report (ITAP) in February 1982 which made initial proposals for the creation of a national electronic infrastructure, has faded considerably as the new emerging Cable TV industry faced up to the harsh commercial realities.

In the initial Franchise Round advertised in August 1983, the Department of Trade & Industry was eager to see applications that promised the use of advanced technology and offered a range of interactive services. It was hoped that these new networks would provide alternative local telecommunication systems that would compete with the existing British Telecom local network. Amongst the initial applications were Consortia who proposed to offer, not only a TV distribution system with videotex possibilities, but also business data and telephony services. In a few cases, there were proposals for the use of optical fibre in certain parts of the network. It was assumed (and is still assumed) that all these local networks would be financed from the private sector and not from any public funds.

In November 1983, it was announced that the Department of Trade and Industry had awarded the first eleven franchises. British Telecom was involved in five of these schemes as a partner in the Operating Consortia and as a provider of the networks in each case.

(A dual approach had been taken by British Telecom to develop both Multi-channel conventional VHF Coaxial System with final star distribution and an advanced Switched Star System.)

The Operating Companies were dealt an unexpected blow however when the Chancellor of the Exchequer announced the phasing out of capital allowances in his 1984 Budget and this damaged the already precarious economics of Cable TV. The Operators had to re-examine their financial models very carefully to find approaches that would justify them to proceed. It was soon apparent also that expectations by the Government of an early demand for non-entertainment TV services was not to be realised.

The new National Cable Authority who have the responsibility for awarding Cable TV franchises is now established and have advertised additional "rounds" and awarded further franchises. It is important however to note that the UK Cable Authority is in a position to provide a powerful incentive to Operators to offer advanced systems as the legislation allows for a longer franchise period of 23 years to be awarded for a Switched System as compared to a 15 year franchise for a more conventional coaxial tree network.

Currently, British Telecom is constructing three major systems passing a total of over 300,000 homes: the Switched Star System in Westminster London and VHF Coaxial Systems in Aberdeen and Coventry. All three systems are operational.

THE SWITCHED STAR SYSTEM

The technical arguments for off-premises switching on Cable TV Systems are well rehearsed and understood. However, the cost implications and the practical implementations of such systems have in the past overshadowed the technical advantages. In Europe however, where there are national interest considerations and incentives that go far beyond technical elegance, a switched topology has become more preferred than in North America:-

- In the UK, teletext services delivered by the Broadcasters are well established. 18% of new domestic television sets that are purchased are equipped to receive and decode teletext services.

- Home computer penetration in the UK is currently at 20%.

- The fully interactive videotex service PRESTEL run by British Telecom is now profitable and is currently offering home banking and home shopping too. Prestel has more than 60,000 customers of which about half are business customers. Currently, a million pages of information are summoned to those screens each day and over 100,000 electronic mail messages are exchanged every week.

  Telecard, a company in Central London has just opened up a home shopping service offering home delivery of 3,500 supermarket lines (at below store prices) to 8,000 existing Prestel users in London.

- The technology and software for photo videotex services are already available and will be shortly introduced on British Telecom's coaxial system in Milton Keynes.

- The penetration of VCRs in the UK is 38% and is an indication of the demand for greater viewing choice and evidence that discretionary income is out there to be tapped.

These features, together with the current political climate, have encouraged the industry to design systems capable of supporting a range of services that go beyond downstream television entertainment. British Telecom therefore decided to develop and install an advanced system that is capable of offering a sophisticated range of services:-

a. Downstream television capable of providing basic channels, subscription channels and pay-per-view channels.

b. FM Radio - 16 Stereo channels.

c. Interactive videotex - alphanumeric and photographic.

d. Individual on demand access to a video library.

e. An advanced network management system offering a customer database plus a range of customer service facilities including a billing and accounting system.

f. Provision is also made for both low speed telemetry services and high speed data, although this is not currently being offered in Westminster.

Although a coaxial tree structured network is the most economic way of delivering downstream entertainment services, when it comes to coping with the large number of individually routed signals that is demanded by such a comprehensive range of services, the problems of congestion, delay, addressability, security and noise become awesome. A single star network would overcome most of these problems but, of course, the cost of providing dedicated broadband paths from a headend to each customer would be prohibitive.

The BT Switched Star System locates a switch in the network near the customer so that communication from the headend to that switch is provided on shared primary circuits. The switch also acts as a common access point and message concentrator and provides an ideal network-node for the provision of additional intelligence, and concentration and primary transmission-bearers as traffic growth demands.

In the Westminster System where multimode fibre is used, there is, in fact, a "tree element" in the system as optical taps are used on some of the fibres that are carrying the downstream channels.

THE SYSTEM ARCHITECTURE (Figure 1)

The system uses optical fibre transmission in the super primary links to the Hub Sites and also utilises fibre in the primary link from the Hub Sites to the Wideband Switch Points (WSP). Each Switch Point is served by 5 optically tapped fibres for providing downstream channels plus 5 dedicated fibres. One of the dedicated fibres is used for upstream video and for control signals so the 9 remaining downstream fibres terminate on optical receivers. The incoming TV channels are demodulated down to baseband where the channels are switched using DMOS FET devices.

The digitally encoded Radio Channels transmitted on one of the fibres are converted back to analogue form, reconstituted as a conventional FM Radio band, and distributed to the Secondary Link launch module.

The Secondary Link from the Switch to the customer is currently engineered to use discrete small bore coaxial cables (2.9 mm diameter) to each customer. The switch unit can initially provide two switched simultaneous channels to each customer assembled onto carriers at 40 MHz and 56 MHz. FM radio and a pilot signal at 120 MHz are added. The overall loss of the coaxial cable is about 10 dB per 100 metres and the system design allows a span of 500 metres from the switch to the customer.

The current switch is designed to have a maximum capacity of 300 customers, although a smaller switch serving 150 customers is also available. The coaxial launch modules have been physically designed in a modular form to allow for the introduction of fibres into the secondary network when this becomes economic. This would allow a longer reach so it is expected that a larger number of customers could be served from a single Switch Point. It is also expected that by then, the physical size of the WSP will be reduced as a result of an increased level of integration in the switch circuitry.

The equipment at the customers premises consists of 4 units: the Customer termination unit (CTU), a small adaptor which plugs into the UHF input to the TV receiver, a remote infra-red receiver and a hand-held IR key-pad. The equipment converts the incoming VHF channels to UHF and processes the control signals.

OPTICAL TRANSMISSION IN THE PRIMARY PATHS

Digital transmission to provide four TV channels on multimode fibre is, of course, quite feasible but it is also still too expensive to be appropriate for the architecture described above.

The digital transmission costs and the common costs of the receive equipment and codecs located in a switch serving a maximum of 300 customers would not be economic. On the BT system, 4 TV channels are frequency modulated onto a carrier of 345 MHz and then down-converted and placed within an intermediate multiplex extending up to 200 MHz. The IF multiplex intensity-modulates an 850 nm laser and the output is launched into a graded-index fibre of 50 μm core with an attenuation of less than 3.5 dB/km and a bandwidth product of more than 600 MHz km.

Normally the maximum reach of the super primary link without repeaters is 5 km but with the use of a better quality fibre, the span can be increased to 8 km. The receiver is an avalanche photodiode which converts the incoming light back to the IF multiplex and a demodulator, employing a phase locked loop, brings each channel down to baseband. This transmission in concept is deployed on both the super primary and primary routes, although allowances must be made in the power budget for the use of optical splitters in the primary path.

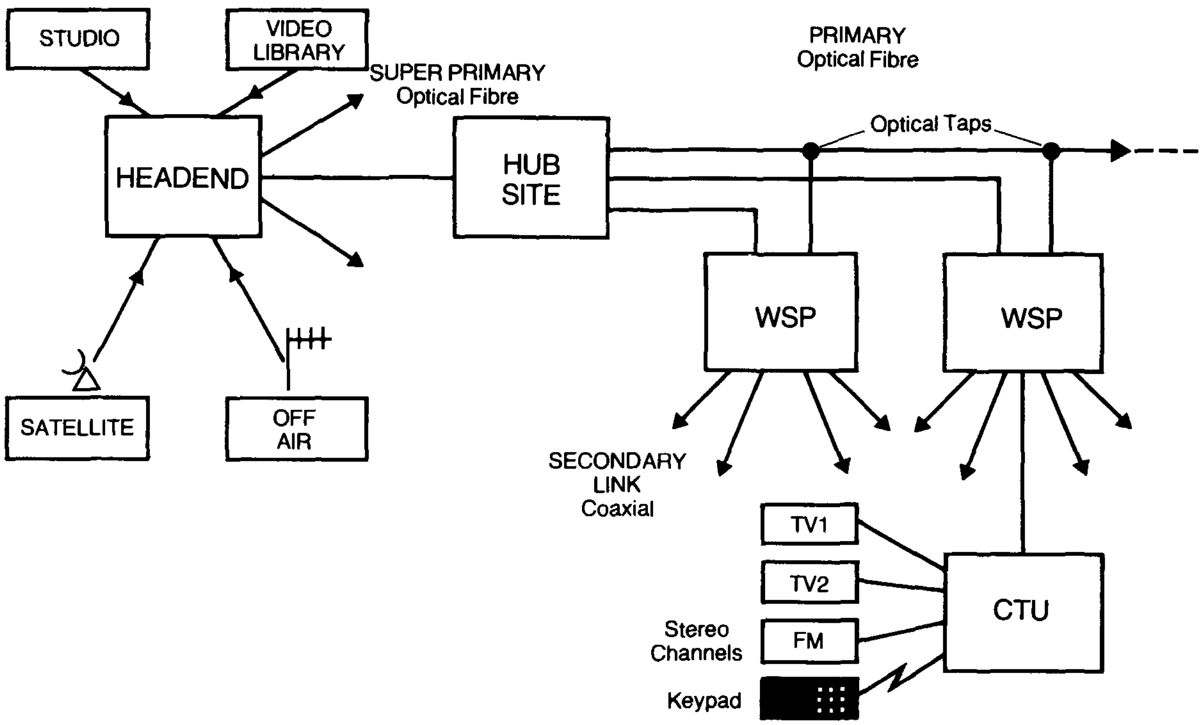
In the Westminster scheme alone, there will eventually be a total of 4,000 fibre kms and this will provide British Telecom with some very valuable experience in the deployment of fibre on such a concentrated scale.

Cables with up to 160 fibres have been specially designed and this has required the development of compact joint organisers to house both fusion joints between fibres and the optical taps on the primary links.

WIDEBAND SWITCH POINTS

As has already been indicated, the switching is performed at baseband. The basic and subscription TV channels are bussed directly to the main switch units which is the heart of the Wideband Switch Point. Currently, each main switch unit serves 300 customers and can be installed on a modular basis as demand for services from each WSP increases. Each switch unit is self-contained with its own control functions responding to signals from the customer launch modules. These main switch units also have access to the video library channels via an auxillary switch so that in total each unit has 30 inputs which are bussed to all 60 outputs (2 outputs per customer).

Fig 1: BT SWITCHED STAR SYSTEM ARCHITECTURE



The Wideband Switch Point also provides local text generators which can be grabbed by any customer who requires access to videotex services and this means that customers can enjoy full videotex facilities - both text and photographic information - without requiring a special videotex terminal and without using the telephone line.

The WSP also provides a further level of control by providing local alarm and maintenance facilities.

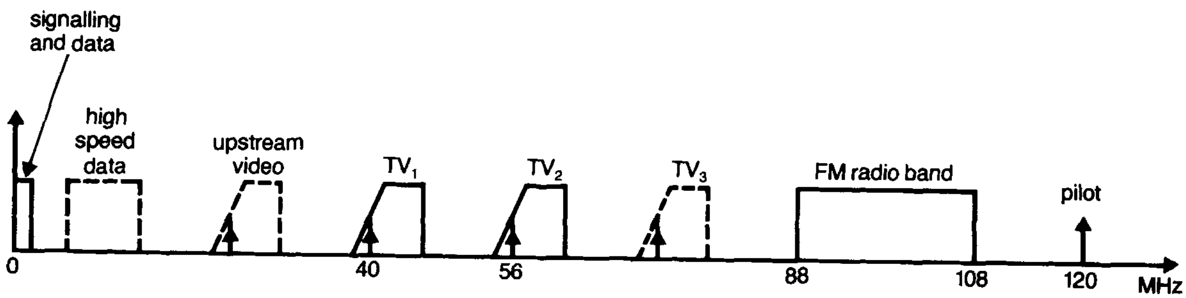
The housing of the Switch Point has represented a major challenge as a large amount of sophisticated electronics must be densely packaged into a field-located cabinet. Equally a significant level of engineering has gone into the whole process of fibre splicing, coaxial jointing, joint enclosures and connectors as these are particularly critical at the WSP nodes.

COAXIAL TRANSMISSION IN THE SECONDARY PATH

The launch module housed in the WSP takes two baseband video channels and amplitude modulates them onto carriers at 40 MHz and 56 MHz in standard vestigial sideband format (VSBAM). The launch module also accepts FM radio in its normal frequency band, along with a 120 MHz pilot tone. These are presented to the launch module as high impedance inputs. The launch module's task is to adjust relative levels, combine the signals and drive them into the 75 ohm or coaxial cable at its output. The spectrum over the secondary link (Figure 2) includes a signalling channel at the baseband end which is routed through the launch module to the switch control.

The overall secondary link is composed of a number of cable sections: the patch cord within the WSP, the tail cable from the WSP to its associated joint box, the main run of multi-tube cable (up to 30 tubes per cable), the link cable at the distribution point, the overhead or underground feed to the customer, and finally the internal cable in the home. Overall the loss at 100 MHz is around 10 dB/100 m, which allows a reach of 500 m.

Fig 2: SECONDARY LINK SPECTRUM



CUSTOMERS EQUIPMENT

At the Customers Termination Unit the two TV channels are upconverted using a local oscillator set at either 495.25 or 503.25 MHz. This choice allows for the two switched channels to appear at the input of the customers television set at either the standard UHF channels 29 or 31 or at channels 30 and 32. The British Standard Institute has established stringent technical standards for Cable TV (BS6513) particularly for the UHF frequency stability of $\pm$ 20 KHz so the local signal is derived from a 4 MHz crystal by means of a frequency synthesizer.

The secondary link may have an attenuation of up to 50 dB at 100 MHz. At the carrier frequencies of 40 and 56 MHz, the corresponding maximum attenuations are about 32 and 37 dB. The customer equipment has an automatic gain control that compensates for this attenuation so that no installation adjustments are necessary. It works by detecting the level of the pilot signal at 120 MHz. In addition there is an equaliser that is automatically switched in or out to compensate for the attenuation slope introduced by the secondary link cable. The FM radio channel betwen 88 and 108 MHz also passes through the equaliser and a gain control element.

The customer termination unit can currently be located anywhere in the home and can tnen teed two televisions and an FM tuner. A remote infra-red receiver located on or near the TV set receives signals from the key-pad and delivers them to the termination unit via the same coaxial cable that carries the UHF signals to the television.

The customer signals are decoded in the termination unit where the message is processed and each control message is then delivered to the Wideband Switch Point when requested by a polling signal.

The infra-red signalling transmits 8-Bit codes when each button is pressed so that, in due course, an alphanumeric keyboard can be used in conjunction with the IR receiver for electronic mail and teletex.

ENHANCEMENTS AND COST REDUCTIONS

The System in Westminster has been developed, manufactured and installed over a remarkably short timescale with the initial objective of gaining early technical and marketing experience using an advanced system that offers new innovative services. The main thrust was therefore to engineer such a system in readiness for the pilot UK franchises but capable of evolving towards a fully integrated and viable telecommunication network. British Telecom has now embarked on a further programme of enhancements and cost reductions in preparation for future franchise applications:-

a. The re-engineering of the Wideband Switch Point Framework.

b. Significant integration of the switch circuit which will not only provide substantial reductions in cost but also in physical size.

c. Re-engineering of the Customer Equipment that will provide enhanced customer options and useful cost savings.

d. The introduction of single mode fibre in the primary links which will allow longer unrepeatered paths and more extensive use of optical splitting at the Hub Sites. This will bring further cost savings as well as offering much greater bandwidth with substantial evolutionary potential.

e. Further useful cost reductions can be achieved by multiplexing all the switched channels and services for two customers onto a single secondary cable and then splitting them at the final distribution point.

Over and above these immediate enhancements, British Telecom is continually evaluating three further potential enhancement/cost reduction opportunities:-

*An increase in the number of channels per fibre - particularly with the use of single mode fibre which will clearly bring cost savings in both fibre and in the reduction of optical devices.

*The development of optical fibre secondary links which will reduce duct-occupancy, give a longer transmission reach and minimise ingress problems.

*The introduction of digital techniques for the transmission of television pictures.

ECONOMIC FACTORS

The System under construction in Central London is substantially more expensive than conventional Cable TV networks not only because it is a new system using new technologies and offering new services but because it has been initially manufactured in relatively small quantities to serve just one franchise area. Throughout the development programme, there has been an underlying objective to produce a cost competitive system that will challenge the existing coaxial technology that currently has the great twin advantages of engineering maturity and large volume production. The initial enhancements listed above, when implemented on relatively small scale production, will bring the cost of the Switched Star System within 15 to 20% of the cost of a VHF Coaxial System that uses baseband scrambling constructed in a UK situation and meeting British Standard Institute Standards.

It is recognised, of course, that an incremental cost of 20% is very substantial in an industry that is keen to identify and exploit a saving of just 1%.

The Switched Star System is an advanced system that offers integrated services that are not available on conventional coaxial systems with a potential revenue from these additional features that goes beyond the income normally achieved by a successful MSO:-

*Impulse pay-per-view.

*Videotex and Photo videotex with gateways to Prestel and other information services with already established home shopping home banking services.

*Individual on-demand video library service.

*Video conferencing.

*High speed access to the national Packet Switched System.

FUTURE PROSPECTS

The use of single mode optical fibre and out-stationed flexibility points is compatible with the activities of most of the world's Post and Telecommunications Operators as they modernise their networks to provide the integrated services digital network (ISDN).

British Telecom, along with other European PTTs, is currently actively involved in establishing standards in preparation for Integrated Broadband Local Networks sometimes described as Broadband ISDN. These networks will be all digital networks capable of supporting a complex range of services including full broadcast quality television. (I leave it up to the reader to speculate on the implications that this will have to regulators, governments and broadcasters.) The Westminster Switched Star System, developed particularly with entertainment television in mind but with evolutionary potential, is one of the world's first steps towards the integrated broadband local networks of the future.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the contributions of Mr W K Ritchie, Mr E J Powter, Dr J R Fox and Dr R T Boyd.

THE DESIGN OF A HIGH EFFICIENCY CATV TRUNK POWER SUPPLY

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ABSTRACT

The advent of new technologies in modern CATV distribution electronics has placed increased importance on the operation of the station power supply, especially in feedforward and parallel hybrid station configurations. This paper addresses some of the important areas recently researched by Scientific-Atlanta in the design of a new switching regulated D.C. station power supply which accommodates all possible station configurations and combinations of gain stage technologies. Power circuit topologies and control circuit implementations are compared, and discussion is given to the author's chosen implementation.

INTRODUCTION

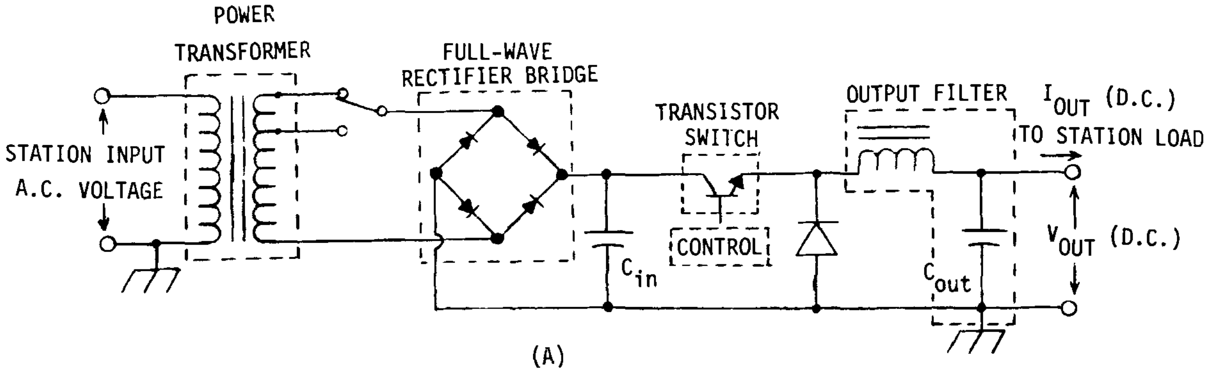
System powering costs and reliability are areas of increasing concern to system operators today as they work to improve service to their customers as well as keep operational and maintenance costs at a minimum. CATV station power supply efficiency and reliability bear directly on these aspects of system performance. Just as improvements in amplifier technology such as hybridized feedforward and parallel hybrid gain stages have enabled enhanced system distortion and reliability performance, recent advances in semiconductor technology and linear control integrated circuits have contributed to the design of more efficient and reliable switching regulated power supplies.

Advanced technology is incorporated in the design of Scientific-Atlanta's trunk station power supply yielding higher efficiency, lower operating temperature, and increased power handling capability. The discussion that follows addresses the various concerns involved in the design of advanced switching regulated D.C. power supplies for CATV amplifier stations. It is the purpose of this discussion to shed light on an area of CATV distribution equipment that is often not adequately addressed.

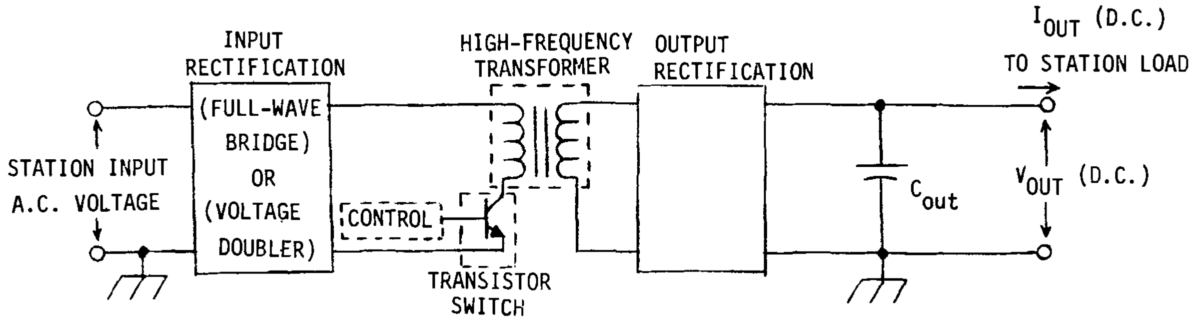
TOPOLOGY CHOICES

The function of the station power supply is to convert the A.C. voltage at the station power input to a well regulated D.C. voltage suitable for use in powering the equipment inside the station. It also provides line isolation for safety and performance reasons. One of the earlier and simpler forms of this supply is the power transformer coupled linear series-pass regulator. Due to its simplicity and low cost this system is still commonly used, particularly in the feeder area of CATV distribution plant. However, the low efficiency and high heat generation of these units makes them less than an optimal solution, particularly where higher output currents are required.

Switching regulated power conversion offers the advantage of achieving greater efficiency in the conversion process, resulting in lower power consumption and less heat generation within the station housing. The two major approaches to switching power conversion for use in CATV stations differ basically in their means of achieving line isolation. Figure 1 (a) shows a power transformer coupled version of a buck-derived step-down switching regulator. Figure 1 (b) shows an "off-line" high frequency transformer coupled switching regulator.



(A)



(B)

FIGURE 1

The general circuit topology shown in Figure 1 (a) provides line isolation through the use of a power transformer to couple the low frequency A.C. input to the station. This transformer breaks any complete direct current path between the input of the station and the output of the supply. A.C. input voltage is transformed to a chosen level by the transformer and supplied to the rectifier circuit which, in conjunction with an input capacitor converts this voltage to an unregulated D.C. voltage. The power switching circuitry produces a pulse train waveform from the unregulated D.C. input voltage at a predetermined frequency and filters the waveform to provide a fixed D.C. output voltage. The control method and components used to accomplish the power switching and filtering functions vary among designs, but the overall function is essentially the same. This particular aspect will be discussed in more detail later in this paper.

The general circuit topology shown in Figure 1 (b) provides line isolation through the use of a high frequency (in the tens of kilohertz range) transformer (or coupled inductor) in the D.C. to D.C. conversion stage. Designs based on this general architecture are often referred to as "off-line" or "transformerless" (although this is an inaccurate classification since almost all employ some type of transformer) because they rectify the A.C. voltage directly from the input line without a power transformer. The rectified voltage is chopped at a high frequency by the power switching circuitry and applied to the primary side of a high frequency transformer, which transforms the high frequency voltage waveform to a predetermined level at the secondary side. At this point the waveform is rectified and filtered, providing a regulated D.C. output voltage. In a version called the "Flyback", the transformer is used as an energy storage coupled inductor.

Both of these topologies essentially quantize the input power then filter and release this energy to the load at a well regulated and controlled voltage. Since this energy is merely transferred in a controlled manner as required from the input to the load, rather than dissipated as in the linear series regulator, the efficiency of these designs is much higher. Given today's state of the art in control system integrated circuits, power semiconductors, and other components, efficiencies at or above 80% can be attained in sophisticated designs which are derivatives of either of the general switching type topologies previously discussed.

For a given power output capability, the "off-line" type of topology can offer a size advantage over the power transformer coupled type. The higher frequency transformer which the "off-line" unit employs in the D.C. to D.C. conversion stage can be physically smaller than the line frequency transformer employed in the input stage of the power transformer coupled topology. The "off-line" type is also more easily implemented where multiple D.C. output voltages are required. These features have led to the increasing popularity of "off-line" designs in the general purpose (off the shelf) power supply and computer hardware power supply fields, where size, weight, and multiple output voltage capability are major concerns.

However, there are some concerns with using direct "off-line" rectification topologies in a CATV distribution plant station product. Without a transformer coupling to the input of the station, small diode imbalances and leakage currents in the electrolytic input capacitors can set up a small amount of D.C. current which flows through the coaxial cable. D.C. current flow can cause galvanic corrosion between dissimilar metal interfaces (i.e., splices, coax to housing connectors, etc.), especially in the presence of humidity.

This problem was prevalent in the early days of cable TV, where half-wave rectification was used without power transformer isolation. The large D.C. currents caused extensive corrosion problems. Although lab tests indicate the magnitude of D.C. current flow caused by direct full-wave rectification is relatively small, the long term effects of small, steady state D.C. current flow on cable plant remains to be seen. Connector reliability concerns, as well as signal ingress/egress associated with corroded "leaky" connector/cable ground interfaces, could pose significant problems for the system operators.

Another concern with "off-line" topologies lies in the need for special attention to input surge protection. The line frequency power transformer used in power transformer coupled topologies provides an inherently good measure of surge absorption and attenuation, particularly for the fast rise-time impulse and high frequency oscillatory high voltage waveforms associated with power grid switching transients and lightning strokes.

Because of the high reliability risk associated with galvanic corrosion and transient voltage protection and the need for maximum system reliability, we have chosen to pursue a new control method and component technology in the design of a trunk station switching power supply which retains the power transformer coupled topology.

A NEW DESIGN

With the development of feedforward amplifier modules, trunk station system configurations were re-evaluated to determine maximum D.C. current and power consumption figures which the station power supply would need to be capable of supplying in order to function in any station configuration. The maximum current configuration was determined to be that of a feedforward trunk amplifier, with feedforward bridging amplifier, dual hybrid reverse amplifier, automatic control module, and status monitor module. This configuration could require a maximum of 2.7 amps at 24 volts from the station D.C. power supply, with a nominal requirement of 2.5 amps. Other station configurations would require less D.C. current, but a 3 ampere output capability was chosen as the design goal which would allow for future module expansion.

As previously mentioned, the design chosen involves a transformer coupled switching regulated supply with an enhanced power transformer design and an improved D.C. to D.C. converter design. Figure 2 shows the

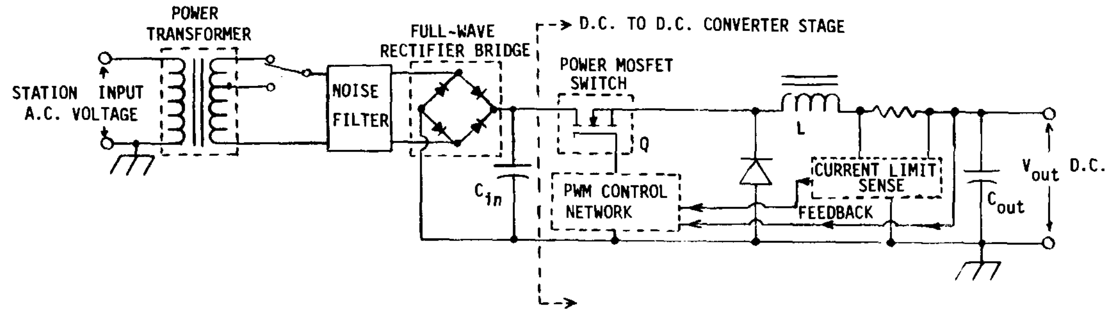


FIGURE 2

basic system diagram of the overall supply topology. In this topology, A.C. power is transformed from the input A.C. voltage level at the station to a selected A.C. voltage at the secondary (output) of the power transformer. It then passes through a common/differential mode noise filter to the input of a full wave bridge rectifier tied to the input capacitor of the D.C. to D.C. converter section. The power transformer performs a level shifting and isolation function and the noise filter attenuates any high frequency noise generated in the D.C. to D.C. converter which can be transmitted back through the transformer to the line. The full wave bridge rectifier gates the energy from each half cycle of the secondary A.C. waveform, applying it to the D.C. to D.C. converter input filter capacitor for storage and filtering. This provides an unregulated D.C. voltage to the D.C to D.C. converter.

This basic type of D.C. to D.C. conversion stage is generally referred to as a "buck" or step-down switching regulator. It efficiently converts a higher D.C. voltage to a lower D.C. voltage. Generally in this type of design, a pulse generator, controlled by a feedback loop from the supply output, pulses Q (the transistor switch) between full on (saturated) and off states to transfer energy from the input filter capacitor to the output filter elements L and C which act as an averaging filter, converting the pulses from Q into a D.C. voltage. To an approximation the relationship between input and output voltage can be expressed by:

$$E_{out} = \frac{t_{on}}{t_{on} + t_{off}} E_{in} \qquad (1)$$

where: t_{on} = on time of transistor switch Q
t_{off} = off time of transistor switch Q
$(t_{on} + t_{off})$ = switch period
= 1/switching frequency

Earlier CATV station power supply designs used a simple control circuit which held t_{on} relatively constant. As a result, output voltage could only be maintained constant vs. input voltage variations through a change in T_{off}, resulting in a change in switching period ($T_{on} + T_{off}$), and thus changing the switching frequency. This type of control is known as frequency modulation.

However, there are disadvantages to this control method. The broad range of frequencies the supply can assume during line input, load, and temperature variations makes it difficult to filter noise and shield the electromagnetic interference generated by the supply. The output filter elements are difficult to optimize for effectiveness and efficiency since they can't be designed around optimal performance for any set frequency. Lastly, in this topology the switching losses in the switching transistor can be expressed as:

$$P_S = V_{in}\,(D.C.) \times I_o \frac{t_r + t_f}{2(t_{on} + t_{off})} \qquad (2)$$

where t_r and t_f = rise and fall time (turn on and turn off time of switch transistor).

For every factor of two change in frequency (and thus switching period) the switching losses in the switching transistor can increase or decrease by a factor of 2. This in turn affects the overall efficiency of the unit.

Pulse width modulation control allows a switching regulator to operate at a fixed frequency, alleviating the drawbacks of the frequency modulation control technique. Fixed frequency operation allows more optimized component design and use, thus leading to higher efficiency and greater reliability. This method of control was chosen for implementation in the D.C. to D.C. converter stage of this design.

In a pulse width modulation (PWM) control design the switching period (t_{on} + t_{off}) remains constant (constant frequency operation). The on time (t_{on}) of the switching transistor (Q) in Figure 2 is varied in relation to changes in input line voltage. This varies the width of each pulse in the pulse train waveform supplied to the output averaging filter. This maintains the proper energy flow to hold the output voltage constant. This is expressed in Equation (1) with $t_{on} + t_{off}$ = constant. With constant frequency operation, the switching losses in the switching transistor vary less than with frequency modulation control. As shown in Equation (2) for a given D.C. output current switching losses vary only with input voltage since $t_{on} + t_{off}$ = constant.

Another advantage of pulse width modulation control is the ability to incorporate true pulse by pulse current limiting with output current foldback into the control network. In response to the magnitude of overload at the regulator output the on time (t_{on}) of the switching transistor is decreased, until under maximum overload at the output (a short circuit), the on time is decreased to its minimum value. This decreases the power dissipation in the switching transistor thus enabling the regulator to operate indefinitely in that mode without damage.

Recent advances in MOS technology have increased the performance of power MOSFET transistors. Power MOSFET transistors can be switched between full on (saturation) and off in less time than most power bipolar transistors, resulting in lower switching losses. As illustrated in Equation (2) when t_r and t_f decrease, the switching loss P_s decreases. In this design, two power MOSFET transistors were connected in parallel to produce a more power efficient transistor switch.

The use of power MOSFET switching devices and pulse width modulation control enabled the design of the D.C. to D.C. converter stage of the supply to be optimized for fixed frequency operation at a higher switching frequency than previous designs while keeping switching losses low. This allowed a reduction in the size of output filter components as well as an optimization of their D.C. and A.C. characteristics to increase their effectiveness and efficiency at the switching frequency. Overall, the physical size of the D.C. to D.C. converter stage was reduced by 30 percent.

PERFORMANCE RESULTS

The implementation of the advanced control method and component technology discussed, within the power transformer coupled switching regulator topology chosen, yielded practical performance improvements over previous designs. The typical operating efficiency of the new design was increased ten percentage points over its predecessor, and output power capability was increased over fifty percent.

Due to increased efficiency, actual power loss (dissipation) within the supply was reduced when compared with previous designs operated at comparable output voltage and current levels. The reduced dissipation resulted in lower internal ambient and component temperatures within the supply, as installed in the trunk station, when compared with previous designs powering the same station configurations (i.e. loads).

This new design has been operating in CATV systems in the field for 2 years without any significant reported failures or operational problems.

SUMMARY

Advances in the development of new power conversion components by power semiconductor, magnetic materials, and integrated circuit manufacturers have made improvements to switching regulated power supply performance possible. Refinements to newly developed technologies such as current-mode control and series resonant sine wave conversion hold promise for future size and cost reduction beyond what has been accomplished to date.

It is evident from the discussion presented that through careful application of advanced component technology and control methods to proven design topologies, dramatic improvements in CATV station power supply efficiency and thermal reliability can be achieved. The use of reliable, higher efficiency station power supplies can improve the performance of CATV distribution systems, by reducing overall system power consumption without affecting signal quality.

The CATV industry was built on the ideal of using advanced technology to provide a valuable product and quality service to its customers. As the industry matures, system operators must carefully evaluate the impact of equipment performance and reliability on system operation, in order to enhance their ability to provide the quality of service the customer demands.

ACKNOWLEDGEMENTS

The author would like to thank Rezin Pidgeon and Alan Schlenz of Scientific-Atlanta, Inc. and James Godwin for their technical research and suggestions in the development of the design discussed.

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THE GILLCABLE STEREO TELEVISION TESTS

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ABSTRACT

As an aid to its internal evaluation of possible technologies for delivering stereo television, Gillcable ran technical comparison tests of broadcast television (BTSC), FM and Studioline formats under actual system operating conditions. This paper details the results of those tests.

BACKGROUND

The advent of broadcast stereo television has presented the cable industry with technical and marketing challenges of very serious proportion[1, 2, 3]. A full discussion of the issues is beyond the purpose of this paper, however the principal concerns are:

- incompatibility with existing scrambling systems
- incompatibility with baseband converters
- possible degradation of stereo separation in a cable system as a function of signal processing equipment
- degradation of signal to noise in a cable system due to cascaded transmission system noise and reduced aural carrier levels
- miscellaneous other issues including compatibility with microwave transmission equipment, adjacent channel interference, etc.

In response, manufacturers of cable equipment have proposed solutions including both equipment modifications to better handle the broadcast (or BTSC) format and equipment to allow operators to handle stereo sound via various out-of-channel schemes.

The FCC, faced with evidence of very high retrofit costs decided not to rule at this time on the issue of whether cable operators would have to carry broadcast stereo in the transmitted format. Their stated intent is to monitor the development of stereo in the marketplace with an eye to later rulings if necessary[4]. The recent ruling of the DC Court of Appeals overturning the must-carry rules in their entirety may make the FCC issue moot, however there is still to be heard the issue of whether stereo content of a broadcast signal may be modified in format without violating the integrity of the copyrighted product.

THE SCTE STEREO SEMINAR

In January of this year, many of the industry's best authorities in the field gathered at a national SCTE-sponsored seminar to discuss both BTSC and alternate stereo technologies. Although attendees were exposed to many alternative strategies, there was also a distinct lack of field experience, largely unsupported conjecture on subscriber reactions and a lack of real apples-to-apples format comparisons. Based on the limited data available, there were also strongly differing opinions on the probable technical performance of various formats. Gillcable personnel, at least, felt that we did not have sufficient information to make an informed decision on a strategy for our company.

THE GILL FIELD TESTS-PURPOSE

As a first step towards making that decision, Gill determined to run a carefully controlled comparison test including BTSC, FM multiplex and at least one of the advanced formats available. The test was to include both technical performance and subjective listening data. Included within the second would be questions of cost and operating and equipment complexity associated with various schemes as those are very important to the ultimate need to sell the technology to our customers. This report will be limited to the results of the technical tests.

EQUIPMENT

The test configuration was designed for as much flexibility as possible and to provide a variety of equipment so that a particular format might not be judged on the basis of a single sample. To that end, the following were provided:

Signal Sources-Video:
VH-1 video
Video test patterns from a Tektronix model 149A generator
Video from a Zenith model VR-4000 VHS video tape recorder

Signal Sources-Audio:
VH-1 digital audio from a Wegener model 1739-03 demodulator
HI-FI audio from the Zenith VCR
Compact digital disk audio (Realistic model CD-1000)
Pink noise from a Heathkit model AD-1309 generator
Precision audio tones from a Sound Technology model 1410A oscillator

Audio Distribution Amplifier:
ROH model 202B

Transmitters:
Scientific Atlanta model 6350 modulator
Scientific Atlanta model 6380 BTSC encoder
Wegener model 1691A FM modulator
Leaming model FMT615C FM modulator
Leaming model FMT652 Studioline modulator

Receivers:
Zenith BTSC adaptor for Z-TAC premium decoder (prototype)
Zenith model CV524 BTSC adaptor for VCR
Sony model MLV1100 BTSC television adaptor
Realistic model STA110 FM receiver
W&S model SM2001 tracking FM stereo tuner
Studioline receiver

Measurement Equipment:
Sound Technology model 1710A audio distortion analyzer
TFT model 850 BTSC analyzer
Heathkit model AD1308 audio spectrum analyzer

The original intent to have multiple BTSC encoders available had to be scrapped as the Wegener unit was withdrawn from the test.

All sources were connected to a common audio distribution amplifier, then fed to the individual modulators. This allowed maximum flexibility in interchanging audio sources. At the receiving end, RF splitters and attenuators were used to feed RF to all equipment. All decoders were connected to an external switching box, then to the auxiliary input of the Realistic FM receiver. For subjective listening purposes, it was felt that this eliminated factors related to the amplification and speaker equipment. Technical data was generally taken at the output of the passive switching box to eliminate any possible noise contributions from the preamplification stages of the receiver.

TEST CONDITIONS

In the Gill system, the earth station receiving site and laboratories are located approximately five miles from the headend. A transportation trunkline of ten amplifiers length connects them. For this test, the subcarriers of VH-1 were carried on a separate, dedicated Catel model VFMS2000 video FM link. This allowed the deviation to be increased for maximum signal to noise without interaction with the video signal. VH-1 was chosen initially because of its superior format for satellite link transmission of audio.

The test point in the laboratories is located 12 amplifiers deep in the transmission system. The measured carrier-to-noise ratio on the special video channel set up for the tests was 47 dB. This allowed tests to be made at various C/N ratios up to that level.

The aural carrier with BTSC encoding was at the normal 15 dB below the luminance carrier. FM multiplex transmission was carried 10 dB below video as is the standard at Gill. The Studioline transmission was carried 15 dB below video, even though the manufacturer claims satisfactory performance should be attainable with carriage 25 dB down. We felt that there was no point in needlessly degrading performance unless system loading factors required it.

Back-to-back tests were made with certain combinations of equipment to determine measurement capabilities. The results will be mentioned with the discussions of individual tests, where relevant.

TEST RESULTS

Signal to Noise

Since expected signal to noise performance was the area that engendered the greatest disagreement among the SCTE seminar participants, a great deal of attention was paid to these measurements[5, 6]. Data was taken for all combinations of equipment under conditions of varying carrier-to-noise ratios.

In the case of BTSC, data was taken with various video conditions to measure the effect of buzz components on overall audio noise. This was done because the EIA's earlier reported test results had shown significant noise increase in the presence of video, multipath and video transmitter incidental carrier phase modulation (ICPM)[7].

The measurement method used was to insert a 1 kHz tone into a given channel at a level sufficient to produce full modulation. After measurement of the recovered audio level, the tone was removed and the level of the remaining broadband noise was measured. We recognize that in systems using active noise reduction circuitry (both BTSC and Studioline) this method does not measure instantaneous signal to noise but rather dynamic range, however we lacked equipment to do the more complex notched carrier noise measurements required for true signal to noise measurements under those conditions. It should also be noted that our measurement method sums together both gaussian noise and discreet noise components (such as buzz components related to video) and should therefore be characterized as "signal-to-crud" ratio. This was felt to be acceptable since any audible spurious noise degrades the quality perception to a listener.

In all cases, measurements were made separately on left and right channels, averaged, and the results rounded to the nearest whole decibel.

TABLE 1-AUDIO SIGNAL TO NOISE RATIOS

	Video Carrier/Noise Ratio *		
	47dB	41dB	35dB
Studioline	82dB	82dB	80dB
FM-W&S Receiver	59dB		
FM-Realistic Receiver	57dB	49dB	43dB
BTSC-Zenith Z-TAC Stereo Adapter			
Blank Black Screen	52dB		
Active Video	55dB		
"Buzz Pattern"	52dB		
BTSC-Zenith VCR Stereo Adapter			
Blank Black Screen	61dB		
Active Video	63dB	60dB	58dB
"Buzz Pattern"	58dB		
BTSC-Sony TV Stereo Adapter			
Blank Black Screen	57dB		
Active Video	57dB	53dB	46dB
"Buzz Pattern"	53dB		

*Other test carriers were varied accordingly

The measurement test limit, determined by connecting the audio source through the distribution amplifier to the audio analyzer was 94 dB.

Several observations can be made about the test results. First, of course, is that the Studioline format performed very well in all cases. The lack of degradation as the carrier-to-noise ratio was decreased would seem to be an indication that internal Studioline equipment noise sources, rather than distribution system noise, is the limiting factor. This is borne out by the lack of significant change between back-to-back equipment connection (measured at 84 dB) and that through the 12 amplifier cascade.

Second, the BTSC, quality in general, also degraded more slowly than carrier-to-noise ratio. This would, again, seem to indicate that significant contributions to overall noise are internal to the equipment. The TFT Model 850 BTSC Monitor measured a transmitted S/N ratio of 65 dB for the Scientific Atlanta BTSC encoder.

Third, the FM multiplex signal degraded dB for dB with the decrease in system noise margin. This was the expected result, but caused FM to perform comparatively worse than BTSC in a noisy system. Results were not significantly different between the two FM receivers, nor between the two available modulators.

Subjectively, the differences in noise level between the BTSC and FM (at 47 dB C/N) were difficult to detect during active music programming of the type transmitted by VH-1. During quiet passages, however, both had detectable noise. In evaluating relative noise levels of these two formats, it should be kept in mind that during the test sequences the video modulation level was carefully controlled. Should video modulation exceed normal levels, significant sync buzz occurs in the BTSC signal (just as it now occurs in monaural sound) while the other formats are free from video side-effects.

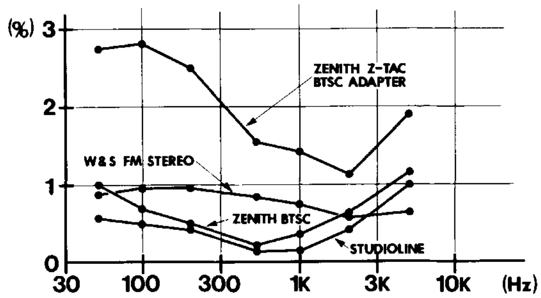
Looking to the future, notice should be taken of the proposed improved system for FM broadcasting proposed by the CBS Technology Center at the recent Chicago ICCE show. This technology holds the promise for an improvement in FM signal-to-noise ratio of 15 dB or more and would clearly give this format an advantage over BTSC[8].

Harmonic Distortion

The second area in which measurements were taken was harmonic distortion of the audio signal in passing through the entire system. Measurements were taken with the audio analyzer and, in the case of BTSC also with the TFT analyzer. In the former case the instrumentation limit was below 0.25% (generally below 0.15%) from 50-20,000 Hz. Video content during these measurements was active VH-1 video. As with noise measurements, data was taken for left and right channels and averaged.

Figure 1 shows the data taken with the audio analyzer for some of the equipment. As can readily be seen, selected samples of all formats achieved a distortion generally below 1%. For unknown reasons, the Zenith stereo adapter for the Z-TAC descrambler exhibited somewhat higher distortion.

Figure 1:



HARMONIC DISTORTION

Other combinations of FM modulators and tuners exhibited similar results with maximum distortion numbers under 1.5% in all cases. The Sony BTSC demodulator, though not plotted, had distortion numbers in the 1-2% range. Transmitted BTSC harmonic distortion was below 1% at all frequencies and below 0.5% from 200-2000 Hz. In general, no clear pattern of preference for a particular format is obvious from our data. It appears that differences in individual equipments was more important than transmission type.

At the suggestion of one of the participants, BTSC total harmonic distortion was measured at 1 kHz as a function of video content with the following results:

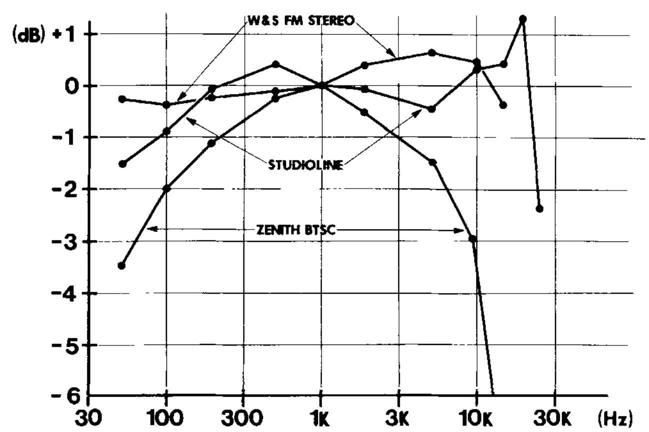
	BTSC STEREO ADAPTER		
VIDEO MODULATION:	SONY TV	ZENITH VCR	ZENITH Z-TAC
BLACK SCREEN	1.6%	0.6%	1.5%
50 IRE GRAY SCREEN	1.6%	1.0%	1.5%
WHITE SCREEN	2.8%	2.5%	2.5%
COLOR BARS	2.0%	0.8%	2.0%

It appears that all of the tested decoders exhibited a degradation as a function of video content and level. Insertion of a 400 Hz high-pass filter in the measurement loop substantially decreased the readings in all cases, indicating that low frequency components were a major contributor.

Frequency Response

Overall system gain as a function of frequency was measured for all systems using the distortion analyzer and precision oscillator. In the case of BTSC, the transmitted response was also plotted using the TFT analyzer. The test instrumentation was flat within 0.5 dB to 10 kHz, rolling off to 1.15 dB at 25 kHz. Figure 2 is a plot of several of the systems.

Figure 2:



FREQUENCY RESPONSE

In the case of BTSC, the upper and lower 3 dB points are very similar for the Sony equipment. The Zenith VCR adapter is similar, except for less low-end rolloff. Interestingly enough, the transmitted BTSC signal was quite flat with no low-end rolloff and only 0.8 dB at 10 kHz. At 15 kHz, the transmitted signal was down 5.8 dB. It would seem, therefore, that the principal contributor to the relatively poor frequency response of the BTSC equipment was decoders rather than the encoder.

If this kind of suppressed low-frequency response is typical of BTSC decoders (perhaps in an attempt to diminish sync buzz), it perhaps offers an explanation of the "subjective loss of bass response" that was reported by the NCTA's observers in the Chicago tests last year.

The Realistic receiver was similar to the W&S receiver except for a 1.6 dB rolloff at 50 Hz and rapid rolloff after 10 kHz to 6 dB at 15 kHz.

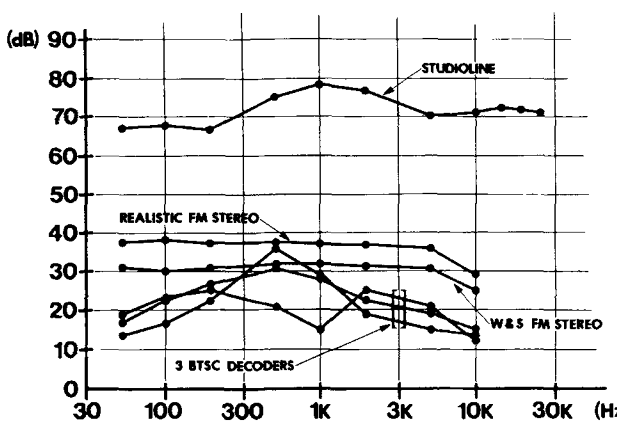
In general, the FM proponents were superior to the BTSC and very similar to the Studioline except for that system's superior high end response.

Stereo Separation

Stereo separation is what differentiates stereo from monophonic transmission, although there is disagreement about how much separation is required or useful. The primary tool used for making separation measurements was the Sound Technology Analyzer. Point-to-point measurements were made for a range of frequencies on each channel with the deviation set to 100% in each case. The channels were averaged and rounded to the nearest dB for the data presented below. In the case of BTSC, data was also taken with the TFT analyzer so that the transmitted separation could be measured independent of any decoder degradation.

Figure 3 below is a graph of the significant results. The very high measured separation of the Studioline system was expected since that format uses independent RF carriers for the left and right channels. The graphed FM separation was taken using the Wegener FM modulator. Separation measured using the Realistic receiver and the Leaming modulator was degraded by approximately 13 dB compared with that measured using the Wegener modulator.

Figure 3:



STEREO SEPARATION

The most widely varying results were obtained using the various BTSC equipment. While the decoders agreed within reasonable limits at low and high audio frequencies, differences of the order of 15 dB were found in the critical mid-ranges, and the results were generally poor compared with either of the other formats tested. Such variations presumedly result from phase and amplitude errors in the decoders either adding to or partially cancelling similar errors in the encoder. When the transmitter was measured with the TFT BTSC Analyzer, the separation was found to be a uniform 21-24 dB from 50-1000 Hz, falling smoothly to 15 dB at 10 kHz and a little over 9 dB at 15 kHz.

In defense of manufacturers of both BTSC encoders and decoders, there has been very little standard measuring equipment on the market to use in factory alignment of their products until the last few months. Hopefully the advent of the TFT and similar products will result in more consistent results in the future.

Nevertheless, the relatively poor showing of the BTSC contenders points out the weakest element in the BTSC system: the companding which is applied only to the L-R signal components in the encoding process. Any relative gain or phase errors between L+R and L-R portions of the aural signal between the encoder and decoder quickly degrade separation. Such errors can result from audio, IF, or RF filtering or any horizontal line rate signals adding to the pilot, for instance.

Finally, it should be pointed out that there is certainly an upper limit of usefulness in stereo separation, just as there is an upper limit of usefulness in S/N performance. Certainly there is a psychoacoustic limit beyond which the human mind cannot detect further improvement, but more importantly, most television viewers will be listening to television through loudspeakers rather than headphones. In that environment, speaker quality, physical separation, room acoustics and listener location all act to limit achievable separation. A discussion of a reasonable electronic separation is beyond the scope of this paper, but readers are urged to review the materials published by such groups as the Audio Engineering Society for further information.

Baseband Converters

Certainly, existing baseband converters are not compatible with BTSC stereo signals if they use audio demodulation and remodulation in order to achieve volume control and mute functions. Without giving up those functions or adding prohibitively to the cost by incorporation BTSC decoders and encoders, the usual approach to stereo is to add an external BTSC decoder whose baseband audio outputs feed external sound amplification equipment[9].

Given that some systems or some customers may elect not to add the additional adapter, it is important to know what happens if a BTSC encoded signal is fed through a normal baseband converter and to a stereo television. Since the audio bandpass of the baseband converter may or may not pass the stereo pilot, but will surely not pass all of the L-R sideband, it would be expected that the result would not be identified as quality stereo.

We found that the Z-TAC decoder used for our tests passed a sufficient quantity of the pilot to light the stereo light on the Sony decoder. The resultant sound, compared to monaural sound was nearly identical in our case, except for a slightly audible degradation in S/N. It would be dangerous, however, to draw conclusions about how other decoders or converters would act under similar circumstances.

High-Level Sweep Interference

Given that many cable systems still use high-level interfering system sweep testing, the effect of such signals on the various contenders seemed relevant. Based on subjective judgments, the amount of "pop" audible in BTSC and FM systems was comparible and somewhat objectionable just as it is now in standard monaural television sound and simulcast FM. The Studioline system also reacted to the sweep, but its amplitude seemed to be lower and the duration somewhat longer. No conclusion was reached as to which result represented the highest degree of subscriber irritation. Certainly, in evaluating other high-quality sound systems, such as digital, such interference and its effects should be evaluated. Perhaps the error correction schemes in digital systems will completely eliminate the audible effects.

FINALLY

Carefully constructed subscriber listening tests will be conducted using this equipment under the auspicies of ATC's market research department to determine the reactions of non-expert observers to the various formats under various conditions. Those will be reported separately by ATC at some future time. Nevertheless, our panel of technical observers made a few subjective observations under conditions of live programming which may be of interest.

First, under high-average-modulation-level conditions with typical VH-1 music programming, differences in S/N ratio were not obvious. When pauses in program audio occurred, though, the noise level in both FM and BTSC were noticeable and significantly higher than Studioline. Our observers did not note significant differences between FM and BTSC in this regard. Thus, while the relatively noisier formats may be adequate for popular music formats, only further tests will detect whether movie programming, for instance, will find listeners equally unaware of the differences.

Second, most observers were aware of a quality degradation when switching between either of the other formats and BTSC. It was variously described as a lack of "sharpness", "depth" and/or "crispness." Whether it was due to the lower separation or the inferior frequency response or some other factor could not be determined.

Third, none of the differences between formats was dramatic to a casual listener using loudspeakers. In all cases there was a significant loss of spacial feeling when switching to monaural, even using the same amplifier and speakers. Also, as expected, there was a significant improvement using the external audio system compared to the internal television speaker in the monaural mode.

As expected, the Studioline system far outperformed all other contenders in technical performance and seems to be a very durable system from the standpoint of distribution system degradation. FM simulcasting appears to have an advantage over BTSC, at least at this time, in stereo separation and the resistance of that separation to degradation. BTSC would seem to have a S/N advantage over FM under degraded signal conditions, however widespread adoption of the new CBS technique for improved FM transmission would give FM a significant edge in the future.

The Gill stereo tests are certainly not a comprehensive test of even the three formats represented. Only one BTSC encoder was used, for instance, and a limited sampling of equipment for other formats. Also, the tests considered only the relative technical merits of these formats. The upcoming ATC listening tests will complement the technical data by adding subscriber subjective reactions. Finally, the ATC engineering department intends to run tests concentrating on the BTSC format and will add useful information on such areas as specific degradations of BTSC due to various cable equipment. Engineers called upon to make choices of stereo format for their systems should review all the available literature carefully.

ACKNOWLEDGEMENTS

Many people participated in the Gill tests on various levels. Particular thanks should go to Wegener, Leaming, Studioline, Scientific Atlanta, Zenith, TFT, W&S Systems and Bay Area Interconnect for the loan of equipment and particularly to the engineering personnel of those participants who spent the time to get the equipment to us and make sure it was running correctly. Walt Reames and his crew and Bill Kostka of the Gill Engineering department contributed many hours to construction, coordination and taking of data. Finally, a special note of thanks is owed to Walt Colquitt of ATC and to Frank McClatchie for lending their time and expertise to the project.

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APPENDIX I - INDIVIDUAL TEST DATA

TEST INSTRUMENTATION - MEASURED AT AUDIO D/A OUTPUTS

FREQUENCY	LEFT LEVEL	RIGHT LEVEL	LEFT % DISTORTION	RIGHT % DISTORTION
10 Hz	-1.40 dB	-1.40 dB		
20 Hz	-0.10 dB	-0.10 dB	0.35 %	0.37 %
50 Hz	0.00 dB	0.00 dB	0.07 %	0.04 %
100 Hz	0.00 dB	0.05 dB		
200 Hz	0.00 dB	0.05 dB		
500 Hz	0.00 dB	0.00 dB	0.055%	0.03 %
1 kHz	0.00 dB	0.00 dB	0.055%	0.03 %
2 kHz	0.00 dB	0.00 dB		
5 kHz	-0.05 dB	-0.05 dB	0.12 %	0.08 %
10 kHz	-0.20 dB	-0.20 dB	0.14 %	0.13 %
15 kHz	-0.45 dB	-0.50 dB	0.22 %	0.14 %
20 kHz	-0.80 dB	-0.80 dB	0.21 %	0.14 %
25 kHz	-1.20 dB	-1.10 dB		

Signal to noise with 400 Hz HPF and 30 kHz LPF: Left Channel: 93.5 dB
Right Channel: 95.0 dB

BTSC MEASUREMENTS

TRANSMITTED BTSC SIGNAL

EQUIPMENT: Scientific Atlanta Model 6380 BTSC Encoder
TFT Model 850 BTSC Analyzer
Sound Technology Model 1410A Oscillator

	RELATIVE LEVEL		DISTORTION @ 100% MODULATION		S/N RATIO		SEPARATION	
FREQUENCY	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
50 Hz	0.0 dB	0.0 dB	0.88 %	0.59 %			23.7 dB	23.2 dB
100 Hz	0.1 dB	0.0 dB	0.67 %	0.58 %			23.3 dB	24.1 dB
200 Hz	0.1 dB	0.0 dB	0.54 %	0.50 %			23.2 dB	24.0 dB
500 Hz	-1.1 dB	-1.2 dB	0.30 %	0.27 %			23.2 dB	23.5 dB
1 kHz	0.0 dB	0.0 dB	0.34 %	0.33 %	65.3	65.2	21.1 dB	20.8 dB
2 kHz	-0.1 dB	-0.7 dB	0.51 %	0.52 %			15.9 dB	15.9 dB
5 kHz	-0.3 dB	-1.5 dB	0.93 %	0.90 %			13.9 dB	14.3 dB
10 kHz	-0.3 dB	-1.3 dB					14.6 dB	15.1 dB
15 kHz	-4.8 dB	-6.8 dB					9.3 dB	9.4 dB

ZENITH Z-TAC STEREO ADAPTER

EQUIPMENT: Scientific Atlanta Model 6380 BTSC Encoder
Sound Technology Model 1410A Oscillator
Sound Technology Model 1710A Distortion Analyzer

	RELATIVE LEVEL		DISTORTION @ 100% MODULATION		S/N RATIO		SEPARATION	
FREQUENCY	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
50 Hz	-1.7 dB	-1.4 dB	2.75 %	2.75 %			19.4 dB	19.3 dB
100 Hz	-1.0 dB	-0.7 dB	2.85 %	2.70 %			23.0 dB	23.0 dB
200 Hz	-0.7 dB	-0.5 dB	2.50 %	2.50 %			24.5 dB	23.0 dB
500 Hz	-0.4 dB	-0.3 dB	1.55 %	1.55 %			20.2 dB	20.0 dB
1 kHz	0.0 dB	0.0 dB	1.10 %	1.25 %	57.0	54.0	15.0 dB	17.5 dB
2 kHz	-0.15dB	+0.2 dB	1.20 %	1.05 %			26.5 dB	24.7 dB
5 kHz	-0.6 dB	-0.3 dB	2.0 %	1.80 %			21.5 dB	20.6 dB
10 kHz	-3.0 dB	-2.7 dB					12.0 dB	12.0 dB
15 kHz	-32.0 dB	-31.6 dB						

NOTE: **

ZENITH VCR STEREO ADAPTER

EQUIPMENT: Scientific Atlanta Model 6380 BTSC Encoder
Sound Technology Model 1410A Oscillator
Sound Technology Model 1710A Distortion Analyzer
Zenith VCR Stereo Adapter with VR-4000 VCR

	RELATIVE LEVEL		DISTORTION @ 100% MODULATION		S/N RATIO		SEPARATION	
FREQUENCY	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
50 Hz	-3.4 dB	-3.2 dB	1.3 %	0.90 %			17.4 dB	17.6 dB
100 Hz	-2.0 dB	-1.8 dB	0.7 %	0.7 %			22.6 dB	22.0 dB
200 Hz	-1.1 dB	-1.0 dB	0.6 %	0.5 %			27.5 dB	25.8 dB
500 Hz	-0.2 dB	-0.2 dB	0.2 %	0.17 %			31.0 dB	30.0 dB
1 kHz	0.0 dB	0.0 dB	0.35%	0.30 %	64.6	64.0	26.5 dB	29.0 dB
2 kHz	-1.15dB	-0.3 dB	0.7 %	0.65 %			21.5 dB	23.5 dB
5 kHz	-1.5 dB	-1.4 dB	1.2 %	1.20 %			18.2 dB	19.9 dB
10 kHz	-3.25dB	-3.3 dB					14.5 dB	15.8 dB
15 kHz	-36.0 dB	-36.0 dB						

NOTE: **

SONY STEREO TELEVISION ADAPTER

EQUIPMENT: Scientific Atlanta Model 6380 BTSC Encoder
Sound Technology Model 1410A Oscillator
Sound Technology Model 1710A Distortion Analyzer
Sony Stereo Television Adapter with Sony KV1976R Television

	RELATIVE LEVEL		DISTORTION @ 100% MODULATION		S/N RATIO		SEPARATION	
FREQUENCY	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
50 Hz	-3.2 dB	-3.4 dB	1.3 %	2.0 %			12.5 dB	12.8 dB
100 Hz	-1.2 dB	-1.25dB	1.7 %	1.95%			16.8 dB	17.0 dB
200 Hz	-0.55dB	-0.6 dB	1.8 %	1.9 %			21.2 dB	22.3 dB
500 Hz	-0.2 dB	-0.25dB	1.75%	1.6 %			35.0 dB	37.0 dB
1 kHz	0.0 dB	0.0 dB	1.45%	1.5 %	57.7	58.5	30.5 dB	27.3 dB
2 kHz	-0.55dB	-0.6 dB	1.1 %	1.1 %			19.5 dB	20.1 dB
5 kHz	-2.0 dB	-2.2 dB	1.5%	1.5 %			15.0 dB	15.4 dB
10 kHz	-3.0 dB	-3.4 dB					12.6 dB	13.7 dB
15 kHz	-30.0 dB	-34.7 dB						

NOTE: **

BTSC S/N AS A FUNCTION OF VIDEO CONTENT

EQUIPMENT: Same as above, except that, instead of active video, specified patterns from the Tektronix waveform generator were used.

SONY STEREO TELEVISION ADAPTER

PATTERN	SIGNAL/NOISE NO FILTER	SIGNAL/NOISE 400 Hz LPF	TOTAL HARMONIC DISTORTION NO FILTER	TOTAL HARMONIC DISTORTION 400 Hz LPF
0 IRE Flat Field	57.0 dB	59.0 dB	1.60 %	1.45 %
50 IRE Flat Field	55.5 dB	58.0 dB	1.60 %	1.45 %
100 IRE Flat Field	54.0 dB	55.6 dB	2.80 %	1.60 %
Color Band	53.0 dB	55.0 dB	2.00 %	1.60 %

ZENITH Z-TAC STEREO ADAPTER

PATTERN	SIGNAL/NOISE NO FILTER	SIGNAL/NOISE 400 Hz LPF	TOTAL HARMONIC DISTORTION NO FILTER	TOTAL HARMONIC DISTORTION 400 Hz LPF
0 IRE Flat Field	52.0 dB	57.7 dB	1.55 %	1.20 %
50 IRE Flat Field	52.5 dB	57.5 dB	1.55 %	1.20 %
100 IRE Flat Field	52.0 dB	57.0 dB	2.40 %	1.25 %
Color Band	51.7 dB	56.0 dB	2.00 %	1.35 %

ZENITH VCR STEREO ADAPTER

PATTERN	SIGNAL/NOISE NO FILTER	SIGNAL/NOISE 400 Hz LPF	TOTAL HARMONIC DISTORTION NO FILTER	TOTAL HARMONIC DISTORTION 400 Hz LPF
0 IRE Flat Field	60.6 dB	64.7 dB	0.60 %	0.26 %
50 IRE Flat Field	60.2 dB	64.3 dB	1.00 %	0.34 %
100 IRE Flat Field	58.2 dB	62.5 dB	2.50 %	0.60 %
Color Band	58.0 dB	59.0 dB	0.85 %	0.55 %

FM MEASUREMENTS

REALISTIC RECEIVER/WEGENER TRANSMITTER

EQUIPMENT: Wegener Model 1691 SW FM Modulator
Sound Technology Model 1410A Oscillator
Sound Technology Model 1710A Distortion Analyzer
Realistic Model STA 110 FM Receiver

FREQUENCY	RELATIVE LEVEL LEFT	RELATIVE LEVEL RIGHT	DISTORTION @ 100% MODULATION LEFT	DISTORTION @ 100% MODULATION RIGHT	S/N RATIO LEFT	S/N RATIO RIGHT	SEPARATION LEFT	SEPARATION RIGHT
50 Hz	-1.2 dB	-1.4 dB	0.36 %	1.15 %			37.8 dB	36.8 dB
100 Hz	-0.6 dB	-0.60dB	0.67 %	0.87 %			37.0 dB	38.6 dB
200 Hz	-0.40dB	-0.4 dB	1.8 %	1.05 %			35.6 dB	38.4 dB
500 Hz	-1.2 dB	-1.2 dB	1.6 %	0.94 %			33.8 dB	40.2 dB
1 kHz	0.0 dB	0.0 dB	1.1 %	1.15 %	57.0	57.0	35.8 dB	36.8 dB
2 kHz	+0.35dB	+0.3 dB	0.85 %	0.90 %			37.4 dB	38.4 dB
5 kHz	+0.4 dB	+0.4 dB	0.90 %	0.91 %			34.4 dB	36.8 dB
10 kHz	-0.7 dB	-0.7 dB					28.2 dB	29.2 dB
15 kHz	-6.2 dB	-6.6 dB						

NOTE: **

REALISTIC RECEIVER/LEAMING FM TRANSMITTER

EQUIPMENT: Leaming Model FMT 615C FM Modulator
Sound Technology Model 1410A Oscillator
Sound Technology Model 1710A Distortion Analyzer
Realistic Model STA 110 FM Receiver

	RELATIVE LEVEL		DISTORTION @ 100% MODULATION		S/N RATIO		SEPARATION	
FREQUENCY	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
50 Hz	-1.5 dB	-1.75dB	0.95 %	0.44 %			18.8 dB	17.6 dB
100 Hz	-0.75dB	-0.85dB	0.90 %	0.97 %			22.2 dB	21.6 dB
200 Hz	-0.3 dB	-0.6 dB	1.20 %	1.70 %			23.6 dB	24.0 dB
500 Hz	0.0 dB	-0.3 dB	1.3 %	1.5 %			23.95dB	24.0 dB
1 kHz	0.0 dB	0.0 dB	0.97 %	1.15 %	57.5	59.0	23.6 dB	24.8 dB
2 kHz	-0.35dB	+0.3 dB	0.82 %	0.87 %			23.6 dB	24.1 dB
5 kHz	0.0 dB	+0.75dB	0.85 %	0.88 %			23.5 dB	24.5 dB
10 kHz	-0.7 dB	0.0 dB					22.4 dB	24.2 dB
15 kHz	-6.2 dB	-5.3 dB						

NOTE: **

W&S SYSTEMS FM RECEIVER/WEGENER FM TRANSMITTER

EQUIPMENT: Wegener Model 1691 SW FM Modulator
Sound Technology Model 1410A Oscillator
Sound Technology Model 1710A Distortion Analyzer
W&S SM 2001 Tracking FM Stereo Receiver

	RELATIVE LEVEL		DISTORTION @ 100% MODULATION		S/N RATIO		SEPARATION	
FREQUENCY	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
50 Hz	-0.3 dB	-0.2 dB	1.0 %	0.68 %			31.0 dB	31.7 dB
100 Hz	-0.2 dB	-0.5 dB	1.0 %	0.82 %			28.2 dB	31.2 dB
200 Hz	-0.15dB	-0.1 dB	1.05 %	0.86 %			30.3 dB	31.1 dB
500 Hz	-0.1 dB	-0.1 dB	0.83 %	0.77 %			30.9 dB	32.2 dB
1 kHz	0.0 dB	0.0 dB	0.78 %	0.63 %	59.7	59.0	30.7 dB	31.3 dB
2 kHz	+0.3 dB	+0.3 dB	0.65 %	0.58 %			30.3 dB	31.1 dB
5 kHz	+0.7 dB	+0.6 dB	0.68 %	0.63 %			30.5 dB	29.9 dB
10 kHz	+0.3 dB	-0.2 dB					28.5 dB	28.5 dB
15 kHz	-0.9 dB	-0.9 dB						

NOTE: **

STUDIOLINE SYSTEM MEASUREMENTS

TRANSMITTER/RECEIVER BACK-TO-BACK MEASUREMENTS

EQUIPMENT: Leaming Model FMT 652 Studioline Modulator
Sound Technology Model 1410A Oscillator
Sound Technology Model 1710A Distortion Analyzer
Studioline Tracking Stereo Receiver

	RELATIVE LEVEL		DISTORTION @ 100% MODULATION		S/N RATIO	
FREQUENCY	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
50 Hz	-2.1 dB	-1.9 dB				
100 Hz	-1.5 dB	-1.0 dB				
500 Hz	-0.9 dB	+0.4 dB				
1 kHz	-0.3 dB	0.0 dB	0.15 %	0.27 %	83.0	85.0
2 kHz	0.0 dB	+0.4 dB				
4 kHz	-0.7 dB	+0.3 dB				
6 kHz	-0.6 dB	+0.2 dB	0.65 %	0.72 %		
8 kHz	-0.4 dB	+0.2 dB				
10 kHz	-0.1 dB	+0.1 dB				
15 kHz	+0.9 dB	0.0 dB				
20 kHz	+0.6 dB	-0.8 dB				
25 kHz	-3.4 dB	-4.2 dB				

NOTE: **

STUDIOLINE SYSTEM TESTS

EQUIPMENT: Leaming Model FMT 652 Studioline Modulator
Sound Technology Model 1410A Oscillator
Sound Technology Model 1710A Distortion Analyzer
Studioline Tracking Stereo Receiver

	RELATIVE LEVEL		DISTORTION @ 100% MODULATION		S/N RATIO		SEPARATION	
FREQUENCY	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
50 Hz	-1.4 dB	-1.6 dB	0.6 %	0.58 %			63.0dB	70.0dB
100 Hz	-0.8 dB	-1.0 dB	0.53 %	0.52 %			66.0dB	70.0dB
200 Hz	-0.7 dB	-0.8 dB	0.48 %	0.36 %			65.0dB	68.0dB
500 Hz	+0.9 dB	-0.6 dB	0.25 %	0.25 %			81.0dB	67.0dB
1 kHz	0.0 dB	0.0 dB	0.18 %	0.19 %	83.5*	81.0*	78.0dB	79.0dB
2 kHz	0.0 dB	0.0 dB	0.45 %	0.41 %			78.0dB	75.0dB
5 kHz	-0.2 dB	-0.6 dB	1.0 %	1.05 %			70.0dB	69.0dB
10 kHz	+0.5 dB	-0.2 dB					73.0dB	70.0dB
15 kHz	-0.2 dB	+0.3 dB					73.0dB	70.5dB
20 kHz	-1.0 dB	+0.15dB					73.0dB	70.5dB
25 kHz	-3.9 dB	-3.0 dB					71.0dB	69.9dB

* Lowering the Studioline carriers by 10 dB to 25 dB below video changed the measured S/N to: 82 dB on the left channel and 81.9 dB on the right channel.

NOTE: **

SIGNAL/NOISE AS A FUNCTION OF RF CARRIER/NOISE - ALL FORMATS

NOTE: For this test, the level of the channel 33 video and aural carrier, the level of the FM simulcast signal and the level of the Studioline carriers were all varied the same amount while all other channels on the system were held constant. VH-1 active video was present during the tests.

	AUDIO SIGNAL/NOISE (dB)			
	BTSC		FM	
EQUIVALENT VIDEO CARRIER/NOISE	ZENITH CV-524	SONY MLV 1100	REALISTIC STA 110	STUDIOLINE
47 dB	62	56	56.5	81.5
41 dB	60	53	49	81.5
35 dB	58.5	46	43	79.5

** FOR RESPONSE MEASUREMENTS, LEVEL SET FOR 100% MODULATION AT 15 kHz, THEN LEFT CONSTANT. DISTORTION AND SEPARATION MEASURED WITH MODULATION SET AT 100% AT EACH FREQUENCY. S/N RATIO MEASURED WITH ACTIVE VH-1 VIDEO PRESENT, 30 kHz LPF ON AUDIO.

THE IMPORTANCE OF SETTING AND MAINTAINING CORRECT SIGNAL AND MODULATION LEVELS IN A CATV SYSTEM CARRYING BTSC STEREO SIGNALS

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ENGINEERING MANAGER
SCIENTIFIC-ATLANTA, INC.

ABSTRACT

There has been much discussion in the recent literature concerning the pro's and con's of carrying BTSC Stereo on a CATV System. The discussions have primarily been associated with one of three subjects:

1. What is the BTSC format?

2. How will the CATV system impair stereo performance?

3. How will the BTSC audio signal impair CATV video performance?

While these discussions have been meaningful and in some cases helpful to the CATV Operator's understanding of how the system works, they have in many cases fallen short of addressing the practicality of setting up the Headend once the operator knows that he will, in fact, be carrying stereo. In this paper, the importance of setting and maintaining correct audio modulation levels, especially with reference to the interface between the BTSC Stereo Encoder and the Video Modulator, will be discussed. This interface is critical to the overall performance of the BTSC system. If the interface is handled incorrectly, stereo performance could be severely impaired, resulting in a multitude of service related calls from a now "stereo-aware" public. No longer will the CATV engineer be able to treat audio as the unimportant portion of the television signal. An increased awareness of audio quality by the public as well as improvements in the state-of-the-art in television stereo processing in the home (VCR's, Stereo Adapters, Stereo TV's), will require that the CATV engineer exercise new levels of caution in the handling of audio information.

Throughout the history of television and certainly throughout the history of CATV, the audio information carried by a television signal has been considered by most of us to be a non-critical item. We simply haven't paid it much attention. After all, the limiting factor in audio quality has always been the consumer's own television set. Why should we be worrying about preserving audio quality in the CATV plant when the customer didn't need or even expect good audio performance out of his set? The answer in most cases is obvious as we have simply ignored audio and have concentrated on providing good quality video to the customer. But recently, and for several reasons, our customers have become much more aware of the benefits of good quality audio. The Compact Disc Player, Stereo or Hi-Fi VCR and now Stereo TV with its associated barrage of consumer advertising have enlightened the CATV customer to the point that he is beginning to expect and in fact demand "good" stereo-audio performance. This is especially true of the new Stereo-TV owner. Because of this increased customer awareness, the CATV operator must begin to better understand what good audio quality really is and how it can be preserved as it passes through the CATV headend. Our methods of processing a stereo signal in the CATV headend can make the difference between the deliberate transmission of actual stereo or the inadvertant transmission of monaural audio. To make matters even worse, mishandling the stereo signal in the CATV headend can also create poor sounding monaural audio for the vast majority of our current customers who are non-stereo equipped.

This paper, in addition to investigating the importance of modulation levels will outline other key areas of concern to the CATV operator to ensure preservation of the stereo signal.

KEY HEADEND INTERFACES

Headends which are configured to receive over-the-satellite stereo-audio broadcasts for subsequent processing and transmission in the BTSC format will require a variety of different equipment. In addition, the equipment may be configured in any of several different ways. Figure 1 outlines a few of the methods of interface between a satellite receiver and BTSC encoder while Figure 2 shows several methods of interface between the BTSC encoder and TV modulator.

The Receiver-Encoder Interface

The method of interface between a satellite receiver and BTSC encoder is dependent upon several factors including the use of uplink, encryption, narrow-band companding or any previously provided out-of-band (FM simulcast) stereo service. The most simple interface, shown in Figure 1A, is made by connecting the encoder and receiver together via the composite video output port of the receiver. In this case, a dual audio subcarrier demodulator within the BTSC encoder

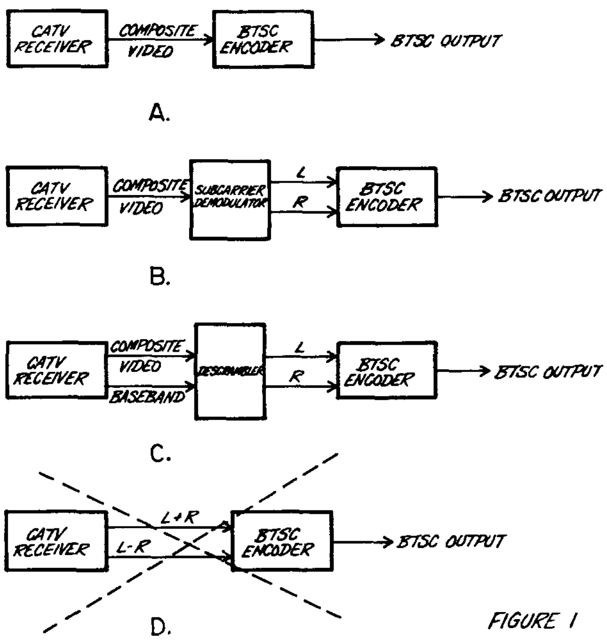


FIGURE 1

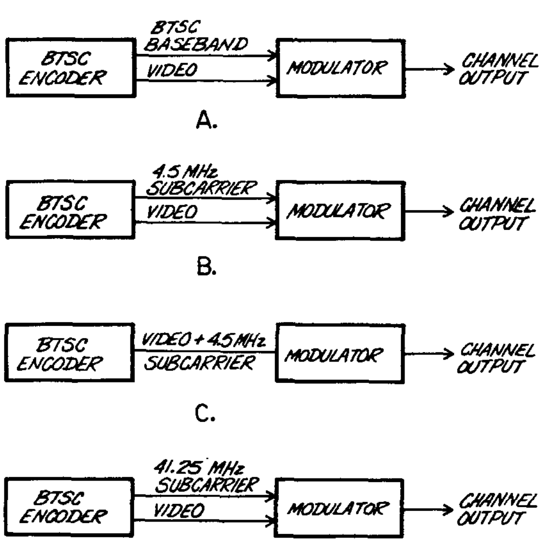


FIGURE 2

itself demodulates the two audio subcarriers to left and right audio for re-encoding into the BTSC format.

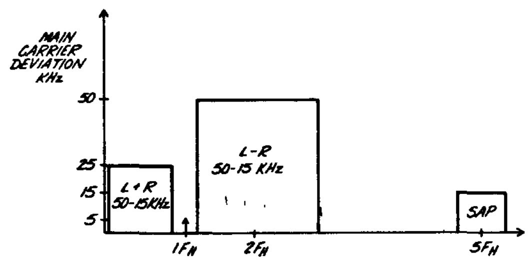
CATV systems which have previously been supplying out-of-band (FM simulcast) stereo signals to their subscribers will likely have access to left and right audio information out of an existing dual subcarrier demodulator. In this case (Figure 1B), the existing subcarrier demodulator and satellite receiver maintain their present interface via the composite video port of the receiver. Left and Right audio out of the subcarrier demodulator are then routed to the encoder for BTSC processing.

With the advent of over-the-satellite encryption, left and right audio will be provided via the headend descrambler as shown in Figure 1C. Of course in this scheme, subcarrier demodulators are no longer necessary. Each of the major manufacturer's encryption schemes provide these necessary stereo outputs.

Another very tempting but highly undesirable practice might be the use of a pair of subcarrier demodulators in a satellite receiver to provide L+R and L-R audio to the BTSC encoder. While L+R and L-R stereo information can certainly be provided by a typical satellite receiver containing two subcarrier demodulators (if the signals are wideband and not compressed like Disney, TMC, and MTV), this is not recommended due to the difficulty in optimizing BTSC stereo performance under these circumstances. This phenomenon will be much better understood after reading later sections of this paper.

The Encoder-Modulator Interface

Figure 2 identifies several of the various methods of interfacing a stereo encoder with a TV Modulator. As shown, the interface can be made at either BTSC composite baseband or at some audio subcarrier assignment such as 4.5 MHz. This is a very key interface in the headend because of the importance of setting and maintaining the correct audio modulation level of the main subcarrier by the composite BTSC signal. Figure 2A indicates the connection directly at composite baseband. Here, the baseband BTSC signal (Figure 3) is connected directly to the baseband audio input port of the TV modulator.



BTSC BASEBAND SPECTRUM

FIGURE 3

In this application the modulator's audio pre-emphasis must be disabled, and its baseband bandwidth and deviation capability must be compatible with BTSC signal requirements (100 Khz bandwidth and 73 KHz deviation). In addition the modulator's overdeviation indicator circuitry must be compatible with the BTSC input or it will erroneously indicate overdeviation all of the time. When interfacing the encoder and modulator at some audio subcarrier as in Figure 2B, 2C, and 2D, the requirements on the modulator are less stringent and simply require adequate bandwidth to ensure minimal degradation to the stereo signal.

While the CATV operator has no control over what goes on inside a manufacturer's piece of equipment and must instead rely on the respective manufacturer's knowledge of handling stereo signals, he does have control over his method of interfacing these various products. As a result, he must understand and eliminate any potential problem areas in these interfaces. Some of these potential problem areas with reference to both the stereo and mono signal are described in the following paragraphs.

PRESERVATION OF THE STEREO SIGNAL

Stereo by definition is the transmission of two separate though perhaps somewhat correlated channels of information. This correlation between Left and Right channel may range from zero in some program material to full correlation (mono) in other program material. Normally, most stereo program material does have some correlation between channels. This signal, known as the common-mode signal because equal amounts are transmitted in each channel, may contain for example the lead vocal and/or a base guitar or drums. The remaining information in each channel would be uncorrelated and would contain the remainder of the stereo information. In order for the stereo signal to be accurately recovered at the subscriber's home, the transmission path, including the CATV headend, must not alter the frequency response, separation, special location, or depth perception of the sound as perceived by the subscriber. All of these parameters unfortunately can be disrupted through mishandling the stereo signal in the interfaces described in Figures 1 and 2. The CATV operator can help to ensure the integrity of the stereo image through his headend by understanding and adhering to a few simple rules:

1. When interfacing with sum (L+R) and difference (L-R) channels the amplitude (or gain) and the group delay of the sum channel path must be exactly equal to that of the difference path.

2. When interfacing with Left and Right channel information, the gain and group delay of the left channel must equal that of the right channel.

3. Audio modulation levels especially with reference to the main audio subcarrier deviation must be set precisely.

Rule #1 is precisely the reason that broadcasters typically do not process signals in the sum and difference format. This is also the reason that Figure 1D is not a recommended practice in interfacing receivers and encoders in a headend. Amplitude and phase errors in the two signal paths become very critical when trying to maintain optimum stereo separation. This can be best understood if you remember that Left and Right channel information is derived from L+R and L-R information through a process called dematrixing. The accuracy of the dematrixing process is totally dependent upon the relative amplitude and phase of the sum and difference signals. This dependance is described by the following equation.

$$\text{Separation (dB)} = 20 \log \left[\frac{(\cos\theta + K\cos\phi)^2 + (\sin\theta)^2}{(\cos\theta - K\cos\phi)^2 + (\sin\theta)^2} \right]$$

When: K = Ratio of L-R to L+R signal level or gain
θ = Phase difference between L+R and L-R
ϕ = Subcarrier phase error

Note: For example that an amplitude error of as little as 1 dB results in stereo separation of no greater than 25 dB if everything else is perfect. Similarly, a 10 degree phase error results in no more than 20 dB of separation if everything else is perfect. Combining amplitude errors with phase errors will quickly erode stereo separation as shown in Figure 4.

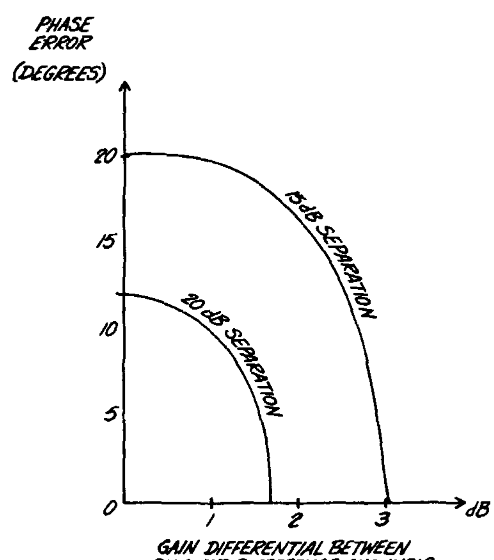


FIGURE 4

What all of this means is that you must be extremely careful if the signal being processed is in the sum and difference format. The equipment being used to transport the signal whether it be cabling, distribution amplifiers, audio switches, etc., must minimize any differences in gain and group delay in the two signal paths. Now I think you can begin to understand the difficulty in trying to interface a receiver and encoder directly at baseband as shown in Figure 1D. With program audio, how could you possibly set signal levels accurately enough to ensure optimum stereo performance? It becomes a virtually impossible task.

Rule #2 is certainly applicable to most of us because in most headends the stereo signal will be routed as Left and Right channel information; commonly referred to as the discrete format. It is interesting to note however that in this case, it is the monaural signal, not the stereo signal that is in jeopardy due to the mishandling of the L and R signals. While it is true that both the special location and depth perception of the sound is dependent upon both the amplitude and phase of the L and R signals and that upsetting either of these parameters will alter the stereo image. This is not nearly as critical to the stereo listener as it may be to the monaural listener. A 1 dB amplitude variation or a 10 degree phase variation between the two channels simply won't make much difference to the stereo signal. In this case it is the monaural listener that will suffer. And remember, in the next few years it will be the monaural listener who will continue to be in the majority of our customer base. This degradation in the monaural signal occurs because prior to transmission in the BTSC format, the Left and Right channel information must first be matrixed into an L+R or monaural signal to ensure compatibility with existing TV sets. If the two channels were completely uncorrelated (no common information between the two signals) then the relative amplitude or phase between the two channels would not create a problem in the L+R signal. But since most stereo programming does have a common-mode component, any phase difference between the Left and Right channels will result in a spectral comb-filter effect which will show up as "suck-outs" within the audio spectrum of monaural sum. In the limit, if the two channels were 180 degrees out of phase, then the common-mode signal would be completely eliminated! This comb-filtering effect can result in a monaural signal which sounds mushy or tinny to the customer.

In reality, most CATV operators have no control over the amplitude or phase of either the discrete or matrixed stereo channel paths.

In the vast majority of circumstances, the signal path between the receiver and encoder, or between the encoder and modulator consists of nothing but a pair of shielded wires. Only rarely is some form of baseband routing or switching utilized in a headend and it is in these cases that the operator must pay strict attention to these rules to ensure adequate performance. There is however one interface which the CATV operator can directly control and which is absolutely crucial in order to maintain adequate stereo performance. I am referring to the need to precisely set and maintain audio modulation levels in the headend.

Setting and Maintaining Precise Modulation Levels

As was shown in Figure 3, the accurate transmission of the BTSC signal requires that precise deviations of the main aural carrier be maintained. These deviations are: 25 KHz for the sum (L+R) signal, 50 KHz for the stereo difference (L-R) signal and 15 KHz for the Second Audio Program. These are the deviations that any stereo decoder or stereo TV will be designed and factory set to receive. Any variation from nominal deviations will cause substantial degradation in channel separation in the stereo signal.

There are several ways to ensure that accurate modulation levels are maintained in the headend. One way is to rely on the CATV equipment manufacturer to produce a quality interface as shown in Figure 2B, 2C and 2D. Here, all modulation levels are set up within the encoder itself. All that is necessary is to provide Left, Right and SAP audio information to the encoder, and the encoder does all of the work for you, precisely setting the relative modulation depths on the main carrier (4.5 MHz) by the BTSC signal. An alternative is to interface at baseband as was shown in Figure 2A and take it upon yourself to accurately set the precise deviation of the main audio carrier. While this approach is certainly feasible, unless the manufacturer has provided you with the necessary tools, it isn't a trivial task.

Figure 5 is a graph which plots errors in main carrier modulation level against stereo separation in an otherwise perfect system.

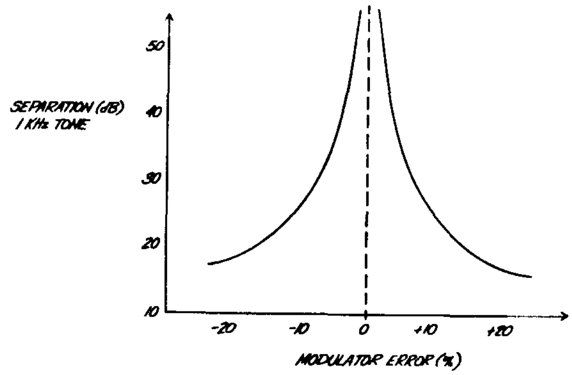


FIGURE 5

This graph clearly indicates the need to keep modulation levels to within +-5% of their optimum value or stereo separation will suffer tremendously. This is not a trivial task when dealing with live audio. In fact, accurately setting the deviation of the system with live audio is next to impossible. For this reason, Scientific-Atlanta has opted to provide the operator with test tone output from the encoder which will help him to precisely set main carrier deviation. The tone, derived within the encoder, is output to the modulator at a fixed frequency and signal level. The operator simply adjusts the audio modulator's deviation pot until the overdeviation lamp just flickers "on". Once this adjustment has been made, the test tone is turned off and the BTSC signal is applied. All signal levels out of the BTSC encoder are precisely referenced to the internal test tone thus ensuring precise main carrier deviations. It has been found that with a properly designed overdeviation light on the aural modulator, this method provides extremely accurate results. It also provides a method of alignment without the use of any test equipment.

Keep in mind that while it is important to accurately set modulation levels in the headend in order to achieve optimum stereo separation, separation alone should not be used as a measure of precise modulation levels. A look at Figure 6 will reveal why.

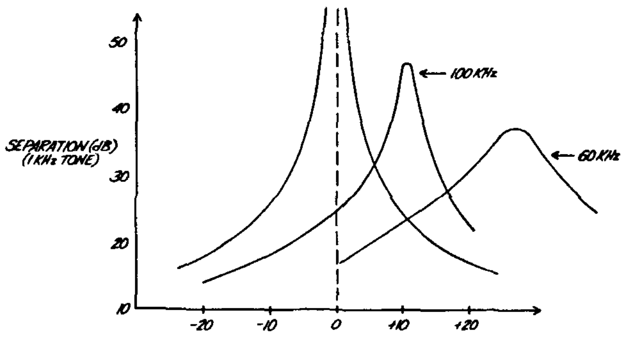


FIGURE 6

The previous discussion may have led you to believe that one method of setting the main carrier deviation would be to drive only one channel of the stereo encoder with audio while adjusting the deviation of the audio modulator until you hear a null in the undriven channel when the signal is monitored on a stereo TV. While this method does produce optimum stereo separation for that particular TV, it is not an accurate method of setting main carrier modulation levels. In fact, it has been found that it is possible to actually correct for imperfections in the bandwidth of the television or elsewhere in the transmission path by allowing errors in the modulation level. As shown in Figure 6, if the bandwidth of the transmission path were reduced to 60 KHz, optimum stereo separation would occur at nearly 27% overdeviation!

In light of the above discussions, one habit which must be eliminated in the casual headend is the daily tweaking of the modulator's deviation pot. Once precise deviation levels are set up, leave them alone except for scheduled maintenance where precise test tones can be used to ensure accuracy. Remember, the modulation level cannot be accurately set in the headend with program audio. It is best set through the use of a precise test tone.

CONCLUSION

Audio in a CATV headend can no longer be ignored. An increased consumer awareness in quality audio is beginning to force the CATV operator to focus his attention on the preservation of good quality stereo audio through the CATV plant. Attention was focused on both the Receiver/Encoder interface and the Encoder/Modulator interface to outline the many and varied methods of arranging such equipment for the transmission of BTSC stereo. In addition, three key rules to follow to ensure the preservation of the stereo signal were outlined. Of these three, perhaps the most important, and certainly the one which the CATV operator has the most control over, is the set-up and maintenance of accurate main-carrier modulation levels.

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THE VCR INTERFACE

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Abstract

The home VCR and "Video Store" are considered by many to be a prime competitive force to Cable TV. However, the VCR is here to stay and must be considered as a factor in the Cable TV system design. With proper marketing, promotion and equipment design, the VCR can be less of a problem and more of an opportunity. To accomplish this, the VCR must be integrated into the home equipment configuration as a supplement to the CATV service. Through consumer education and the installation of a user friendly interface product, the subscriber can remain satisfied that the Cable TV Company is not taking away the usefulness of his own home equipment.

This paper investigates various RF switching approaches to the VCR interface problem, analyzes their "user friendliness" and suggests a VCR- Baseband "afterburner" decoder or a novel RF frequency multiplexing device as the ultimate solution.

Introduction

Industry sources estimate that at the beginning of 1986, 28% to 30% of American homes will have VCRs. This represents a 10% increase in VCR market penetration from 1984 to 1985. It has also been reported by some Cable TV MSOs that nearly 60% of their subscribers own VCRs. A recent A.C. Nielsen study similarly showed that pay-cable subscribers are most likely to own VCRs. Clearly, the home video recorder is an important element to be dealt with in the design and marketing of a Cable TV system. Whether the VCR is a friend or a foe, an opportunity or a problem, depends on how the cable operator reacts.

For the subscriber, or potential subscriber, Cable TV is regarded as a service for which they pay depending upon its desirability, quality and usefulness. The perceived usefulness of Cable TV is largely based upon its economy, convenience and ease of use. Cable TV's desirability stems from its providing of a greater variety of programming than is available from over-air TV or other alternate entertainment sources. Since Cable TV does provide such variety on various and sometimes conflicting schedules, the subscriber often wishes to time-shift record programs on the home VCR for later viewing. Here begins the problem.

Faced with the various interconnection possibilities of the CATV cable, Converter-Decoder, VCR and TV Receiver, the consumer often becomes frustrated and intimidated by the seemingly complicated arrangement. Once connected, the subscriber then finds that he either cannot record premium (scrambled) programming or is only able to view the program being recorded and has greatly reduced the usefulness of his own VCR's features.

In order to maintain subscriber service satisfaction, the Cable TV operator must now consider the home VCR as one of the system parameters and deal with it. A low cost, easy to use VCR interface device must be provided to help the subscriber solve his problems. For maximum utility, the ideal device should provide the following functions:

1. Simple, easy to understand operation
2. Maintain MTS Stereo compatibility
3. Maintain Performance quality
4. Maintain unattended VCR programmability
5. Allow ability to:
   a. View recorded tape
   b. Record Premium while viewing Premium (same)
   c. Record Basic while viewing Basic (same)
   d. Record Basic while viewing Basic (other)
   e. Record Premium while viewing Basic
   f. Record Basic while viewing Premium

Common Approaches

It seems that every technically minded individual in the Cable TV industry has thought of a different answer to the CATV-VCR interconnect problem. Some solutions appear simple and others very sophisticated. A common problem is that these devices are sometimes considered from an engineering point of view and not from the end-user's.

RF switching systems designed to provide for every possibility may be technically elegant and have great appeal to the Cable operator's engineering staff but can be a "head-ache" for the consumer in installation and use. Even after the device is correctly installed, the subscriber must learn which switch to turn to what position, and which channel to be tuned on both the VCR and TV for each seemingly simple desired function. Beyond this, the prospect of teaching the use of the device to other family members or an occasional baby-sitter becomes a monumental task.

Up until now, the two major approaches to the VCR-CATV interconnect problem have been as follows:

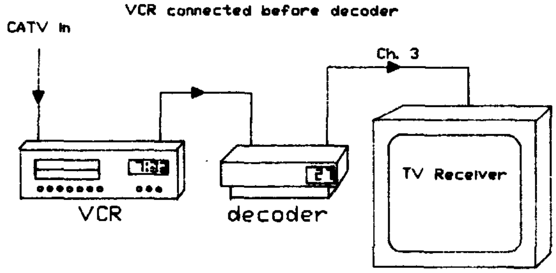
1. Hard-wire interconnect
2. RF Switching

<u>Hard-Wire Interconnect</u>

Figures 1 and 2 show the two possible methods to interconnect a CATV cable, converter-decoder, VCR and TV receiver without extra devices. In Figure 1, the CATV decoder is connected between the VCR and the TV. This arrangement allows the full use of the VCR's features to record any Basic program while viewing any program, Basic or Premium. The VCR's programmability for unattended channel change is retained, but Premium programs cannot be recorded since the signal does not pass through the decoder until after it has passed through the VCR.

Figure 1

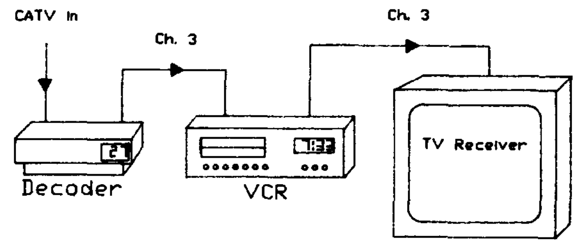
VCR connected before decoder



In order to record Premium programs, the VCR must follow the Decoder as shown in Figure 2. This arrangement renders most of the VCR's tuner features useless, however, since the VCR can only receive the output channel of the CATV decoder.

Figure 2

VCR connected after decoder

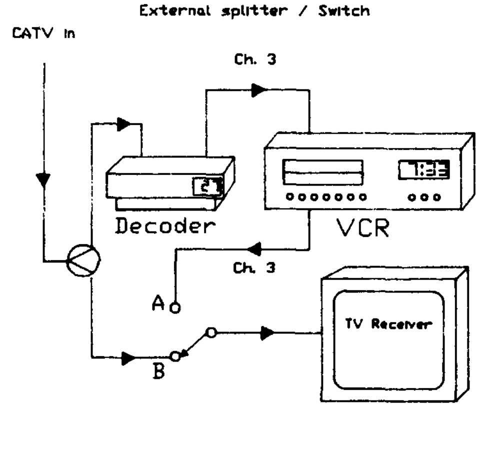


<u>RF Switching</u>

An alternate approach, designed to recover some of the VCR features lost in the hard-wire interconnection is shown in Figure 3. This system uses an external splitter and RF A/B switch arranged in such a way that while any program (Basic or Premium) is being recorded, any Basic program can be viewed. The VCR, however, is still only capable of receiving the CATV decoder's output channel and is incapable of programmable channel change. Operation of the system now begins to become complicated due to the addition of the manually operated A/B switch.

Figure 3

External splitter / Switch



As an attempt to recover more of the functionality of the VCR, an RF switching product incorporating multiple ports, switches and splitters can be used. Figure 4 describes a typical product incorporating two separate switches, one for viewing (three positions: CATV, Premium, VCR) and one for recording (two positions: CATV, Premium) Although this approach does seem to provide for all of the most desired options, it does not allow a programmable unattended VCR to record a premium program followed sequentially by recording a basic program since the VCR has no control over the switching. Additionally, the manual switching is more complicated and might tend to intimidate many high-tech shy subscribers.

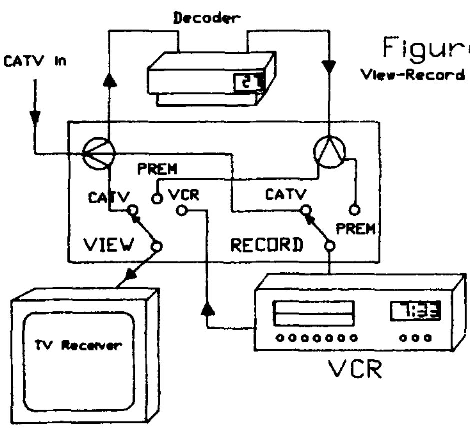
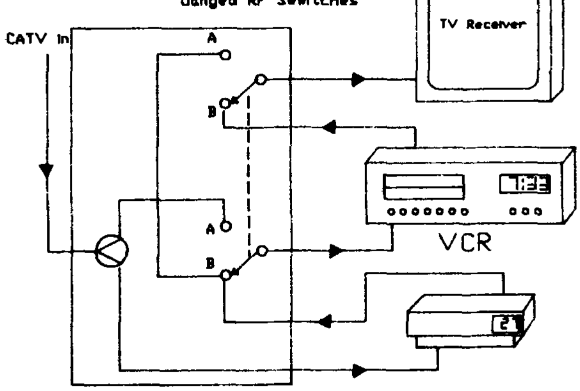


Figure 4
View-Record Switching

In an effort to simplify the switching device operation, the RF switches could be ganged together, as shown in Figure 5. This arrangement is designed to reduce the possible switch positions, and consequently the number of decisions the user must make.

Figure 5
Ganged RF Swwitches

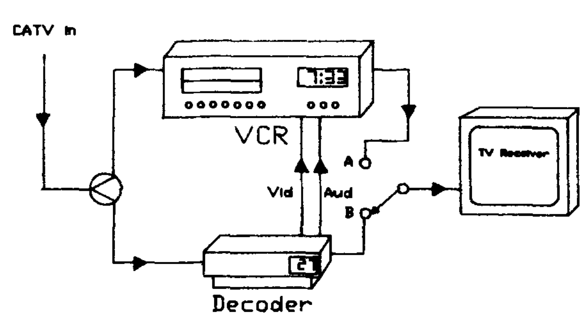


This example shows a product with only two positions. Position A allows the viewing of any (Basic or Premium) program through the use of the CATV decoder tuner, while recording any Basic program through the VCR tuner. Position B allows the viewing of the VCR output or any (Basic or Premium) channel tuned by the CATV decoder tuner, while recording the same program being viewed. A third switch position could be added, with only a small increase in complexity of operation, to further allow the recording of a Premium program while viewing a Basic program.

Even though these solutions appear to simplify operation, switch position and channel selection decisions still have to be made depending upon what the subscriber desires to do. In some switch positions, checking what the VCR is recording is impossible since switching to the "VCR view" mode disconnects the desired signal from the VCR input. Similarly, care must be taken not to change switch positions for viewing alternate programming while VCR recording is in progress.

Figure 6 shows a novel approach using both a two position RF switch device and the Video/Audio outputs of a baseband CATV decoder through the VCR's built in Tuner/Aux. input selector. Some new VCRs even allow the unattended selection of "Tuner" or "Auxiliary" inputs as part of the multi-event programming. With such a VCR, this system allows for all of the desired functions. In operation, however, it is not as simple as it looks. Although there is apparently only one two-position RF switch to be concerned with, there are two more two-position switches in the VCR (TV/VCR switch and Tuner/Aux. switch) which must be manipulated.

Figure 6
Video/Audio - RF Switching



Alternate Approaches

RF switching systems really have one common drawback - the complicated installation and various switch positions make them difficult to use. What really is necessary is a system which does not require the subscriber to think about what he is trying to do.

In an effort to provide the most user utility, while providing simplicity of operation, two alternate approaches to the VCR-CATV interconnection problem are suggested:

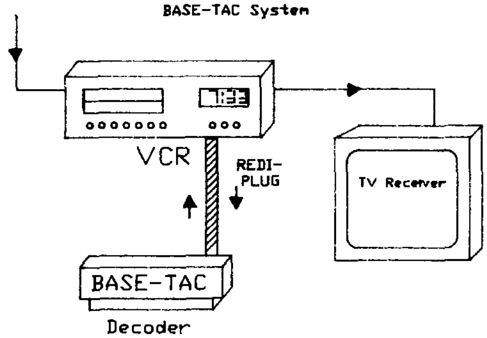
1. VCR "afterburner" baseband decoder ("BASE-TAC")
2. RF Frequency Multiplexing ("VCR Interface")

BASE-TAC

Perhaps the ultimate and lowest cost VCR-Cable interface is the "Afterburner" approach. This system is so named because the premium program descrambling is performed **after** the subscriber receiving equipment's tuner-IF, and demodulation stages. The system depends upon Baseband scrambling techniques, in-band addressing data, and home equipment capable of being adapted. The Zenith BASE-TAC product is a good example of this technique and is compatible with Zenith's Z-TAC SSAVI scrambling.

Figure 7 shows a VCR equipped with a BASE-TAC decoder. All Zenith VCR models since 1984 have been adaptable to a BASE-TAC decoder through a field installable REDI-PLUG. Similarly, a VCR designed with a CENELEC connector for the NTSC Television Receiver Baseband Audio/Video Interface Standard could be used. The REDI-PLUG on the back of the VCR contains all of the necessary interconnects in a single multi-wire cable between the VCR and the BASE-TAC pay TV decoder.

Figure 7
BASE-TAC System



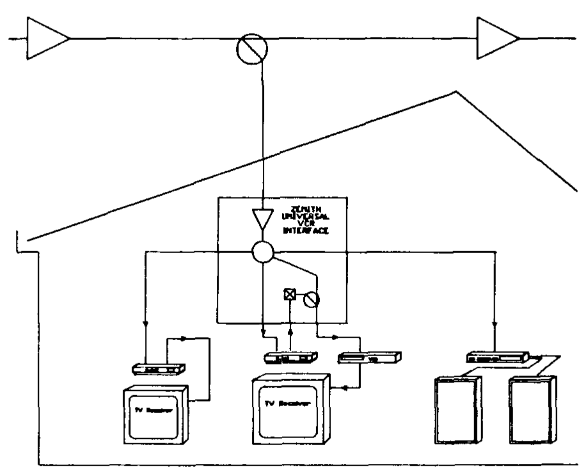
In this approach there is no CATV converter (only the BASE-TAC decoder), there is no splitter, there are no RF switches to be concerned with. The CATV RF signals can be directly connected to the VCR and from the VCR to the TV receiver as in a normal setup. The VCR tunes and demodulates the encoded channel into a baseband signal. The encoded video and addressing data are then routed to the external BASE-TAC decoder through the REDI-PLUG. The decoder, if previously addressed and authorized for the tuned program, will decode the signal and return it to the VCR.

Channel selection for the VCR is accomplished through its own tuner, manually or via its programmable VCR timer. The VCR and TV receiver operate normally without complicated switching and retain all of their features including BTSC stereo compatibility.

The "VCR Interface"

Since the BASE-TAC system relies upon baseband scrambling and adaptable home equipment, it may not be a universally acceptable solution to the CATV-VCR problem at this time. A more general approach is needed to deal with the variety of equipment now in use. The Zenith "VCR Interface" was conceived to provide a simple, low cost universal solution to the Cable TV - VCR interconnection problem. The device does not require manual or automatic switching but supplies all of the functions normally associated with such switchers.

FIGURE 8
UNIVERSAL VCR INTERFACE



The application block diagram of the system is shown in Figure 8. With this approach, instead of switch/time multiplexing the RF signals through a difficult to learn switching system, the signals are **Frequency Multiplexed**. The incoming cable signals are amplified (to compensate for later losses) and split four ways: to a secondary RF output, to the input of the primary pay TV decoder, to an FM receiver output, and to a signal combiner. The Ch 2 or 3 pay TV decoder RF output is fed to an up-converter (mixer - local oscillator) where it is converted to a channel not used on the CATV system. This decoded and up-converted channel is now re-combined with all the signals on the Cable TV system in the signal combiner and passed on to the subscriber's VCR and TV receiver.

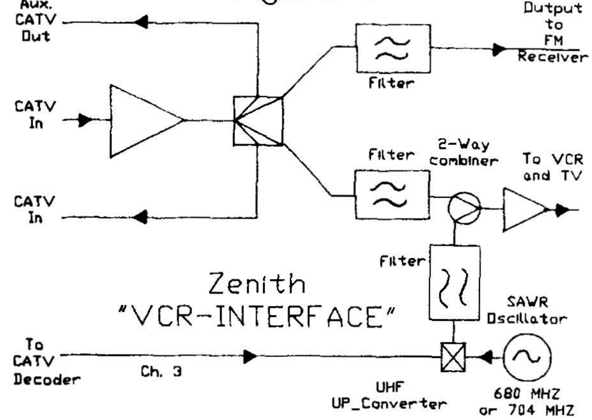
With this arrangement, the subscriber operates his VCR and TV normally, in the same familiar fashion he would without a CATV converter. No confusing RF switching is necessary. No extra thought is necessary to perform the desired viewing and recording functions. Once connected, the "VCR Interface" does not have to be worried about, it can be left out of sight.

Channel selection for viewing or recording is accomplished with the TV's and/or the VCR's tuner. With the TV or VCR tuned to the decoded up-converted channel, channel selection is performed through the CATV converter-decoder. Viewing of one channel while recording another is now possible as well as unattended programmed VCR channel switching from premium to basic programs. By interconnecting several TVs or VCRs, a subscriber could be viewing a premium program, recording a basic program, while others in the home are viewing or recording other basic programs.

A major decision is the choice made for the up-converted output channel. For economical mass-production, a common, standardized output channel must be selected. Ideally an unused CATV band channel would be chosen but due to the lack of standardized channel usage among Cable TV systems, a common channel cannot be identified.

An alternate method is to up-convert to a UHF channel. This serves a dual purpose, it provides a guaranteed unused channel for use and it becomes useful with older non-CATV compatible TVs and VCRs.

Figure 9 shows a detailed block diagram of the VCR Interface. A SAW resonator oscillator (for stability) is used to up-convert the decoder output channel to a UHF output frequency. Two models are made available depending upon the UHF output channel required in the user's area. A 680 MHz oscillator is used for up-conversion from Ch 3 (VHF) to Ch 59 (UHF). Similarly, a 704 MHz oscillator is used to up-convert from Ch 3 (VHF) to Ch 63 (UHF). In either case, the converted decoder output signal is summed with the CATV RF spectrum for delivery to the subscriber's VCR and TV.



In application, the TV and VCR are placed in the "TV" mode (as opposed to the "CATV" mode) to select VHF basic channels or UHF CATV programs (as tuned through the CATV decoder). Viewing or recording other CATV channels while the CATV decoder is otherwise being used, requires switching the TV or VCR to their "CATV" modes.

Figure 10 shows the complete VCR Interface connected to a VCR and TV receiver. Figure 11 describes the input spectrum to the VCR Interface and Figure 12 shows the output spectrum including the additional UHF channel.

FIGURE 10

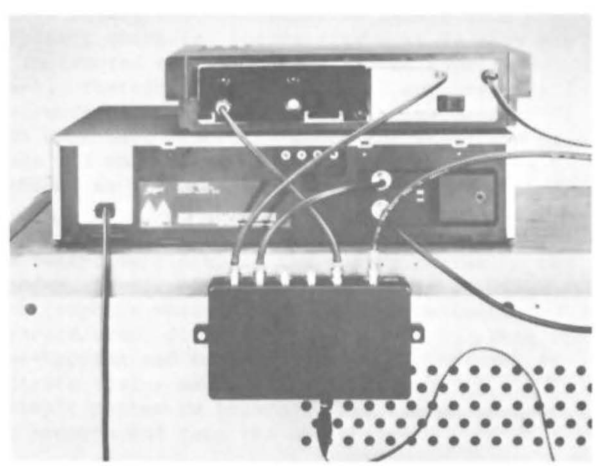


FIGURE 11

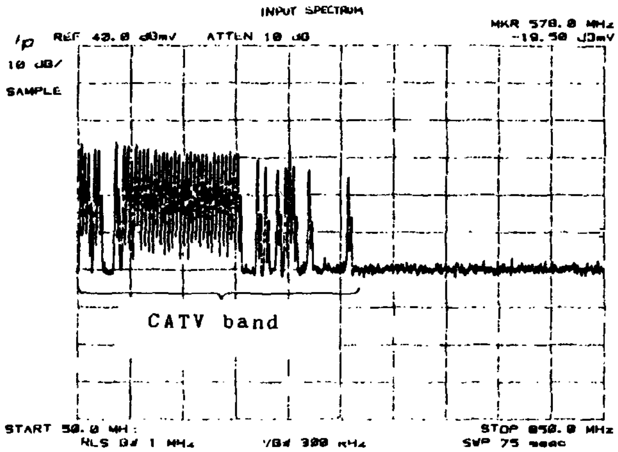
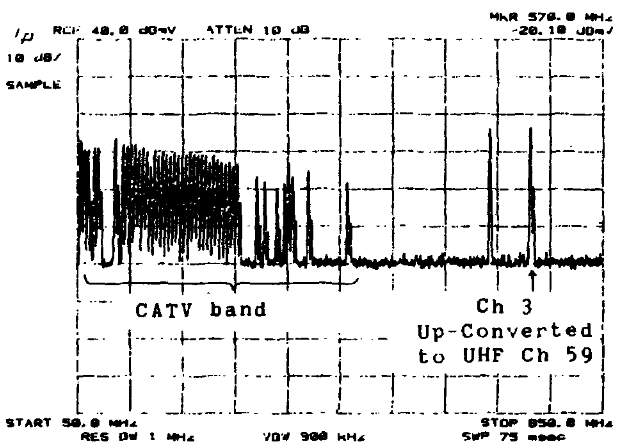


FIGURE 12

Output Spectrum



Conclusion

Several approaches to the problem of interfacing CATV, converter-decoders, VCRs and TV receivers have been described. In an effort to simplify user operation, two new approaches to the solution have been presented: the BASE-TAC "afterburner" approach, and the "VCR Interface" RF Frequency Multiplexing system.

Acknowledgements

The author would like to thank Mr. Vito Brugliara and Mr. George Green for their help and encouragement in the preparation of this paper and to Mr. George Hoeltje, Mr. Mike Nakanishi and Mr. Andrew Babchak for their development of the VCR Interface from an idea to a working product.

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TIME SHIFTING
EASY-TO-USE EVENT PROGRAMMING

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ABSTRACT

Widespread use of VCR's has created a demand for unattended recording of programs delivered through converter/decoders. When used with a timer-equipped VCR, a converter also equipped with a programmable timer can satisfy this requirement.

Event programming of converters is achieved either by adding a timer to a hand-held remote control or by incorporating a timer into the settop unit. However, as many purchasers of VCR's have already found to their chagrin, providing the technical capability for pre-programming events and having a device which is truly user-friendly are not necessarily one and the same thing.

This paper discusses the human-factors considerations affecting the design of one such programmable remote/control timer. Ease of operation is the primary issue discussed in this paper.

★ ★ ★

It wasn't that long ago that watching TV was one of the "simple pleasures" of life in our electronic age. The "cable box" of the early '70s typically consisted of a rotary channel selector with perhaps a fine tuning control. It's output was connected through a matching transformer to a piece of "lead-in" wire which, in turn, was screwed onto the back of the subscriber's TV set.

Today's subscriber to an addresssable CATV system is furnished with a microprocessor-controlled "home terminal unit" capable of tuning over 100 channels and equipped with such features as volume control, an electronic lockout for parental control, favorite channel memories, second-audio-program and stereo capabilities, audio muting, last-channel recall, electronic channel mapping, and a host of operator controlled functions to facilitate PPV or premium programming. Some simplifications have been made, however; we have managed to do away with the fine tuning control and, in most cases, with the matching transformer.

It's not just the delivery of CATV programming that has become more complex. The cable subscriber of the '80s is likely also to have a VCR, perhaps an MTS stereo decoder, and maybe even an outboard IPPV control of some kind, all sitting alongside an elaborate component stereo system. As a by-product of all of this gadgetry our subscriber has also probably accumulated a drawer full of "handy" remote control units. Trying to hook all of this together has turned the "TV corner" of many living rooms into a complicated cross between Rube Goldberg and Mission Control.

One of the chief sources of frustration to new VCR owners has been the discovery that their ability to "time shift" by taping programs unattended for later viewing is severely limited by their CATV converter/decoder. Suppliers of addressable equipment, acutely aware of the roadblocks formed by their products have begun to overcome this shortcoming; in recent months a number of manufacturers have announced new or add-on products aimed at providing subscribers with a means of timing their HTU's to match the capabilities of their VCR's. Most of these amount to a programmable timer housed in the remote control for the home terminal unit. The subscriber programs the remote control unit and sets it front of his cable box. At the appointed hour, the timer sends an IR code to the cable box to turn it on and tune it to the selected channel; at the end of the programmed time, another code is flashed, turning the box off again until the next timed "event."

In meeting this challenge, however, it has become apparent that a potential exists for creating new problems even as the old ones are overcome. Programming of VCR timers is a notoriously complex task which has been further complicated by tiny or hidden controls, unforgiving sequential command structures, and poorly written instructions. Everyone has heard horror stories of the time-delayed Super Bowl game that consisted of two beer commercials and thirty seconds of Jimmy the Greek.

These problems, while perhaps amusing, do not concern the cable operator because he is unlikely to hear complaints that his customers' VCR's are difficult to operate. If the programmable timer for your cable box betrays you, however, who ya gonna call? It thus becomes very important that the designers of time shift devices for cable products learn from the mistakes of their brethren in the VCR business by making their devices as easy to learn and use as possible.

The Programmable Remote Control Unit provided by Oak Communications for its Sigma line of addressable home terminals resembles in concept those of its competitors. The timer function was incorporated into the RCU rather than the settop unit for obvious reasons: it enabled the feature to be introduced without re-engineering the entire product, and it allowed the operator to use his existing stock of HTU's, thus making it a more attractive buy.

Moreover, confining any extra controls or hardware required to a discrete device meant that the operator could provide the capability only to those who desired it rather than to his entire subscriber base. As some have learned from experience, providing subscribers with inoperative controls or indicators is to invite needless calls.

Of course, there is also a down side to isolating the timer function in the remote control unit. The subscriber must remember to leave the RCU where the HTU can "see" it, but Oak's device minimized this problem somewhat through use of two wide-angle infrared LED's. Also, the RCU is small and portable and, as most operator's are aware, can be lost, stolen, dropped, accidentally thrown away, or chewed into rubbish by the family pet. The subscriber is unlikely to seriously blame the operator for this type of loss, however, and a reasonable deposit can help insulate the operator from its effects.

Once it was decided to adopt the remote control concept, Oak's engineers faced the problem of how to design a unit that would incorporate the necessary functions, would be economical to build and sell, yet would still be easy to use.

Strictly from the standpoint of number of functions, the standard IR remote control for Oak's Sigma Decoder with its 21-button keypad was already fairly complex. One early idea was to make a number of the buttons do double duty through use of a so-called PROGRAM key (e.g. PROGRAM + VOLUME UP = Date). While this could have kept the key-count low, it would not have made the device any easier to use; in fact, just the opposite. Similarly, a cursory analysis of the existing VCR market showed such a wide disparity in the ways their timers were incorporated, it was felt we would get in less trouble if we simply ignored them all.

Instead, the content of the message was analyzed and a straightforward means of sending it was provided. Every timer message takes the same form: "Please BEGIN. Turn on my cable box on DATE, tuned to CHANNEL, at START TIME. Then, turn the box off at STOP TIME. That is the END, thank you." Within each message, the longest piece of information was the time; up to four digits plus selection of a.m. or p.m. To make entering the message analogous to a more familiar task it was treated like an entry in a handheld calculator or the equally familiar automatic teller machines; the device would prompt for each bit of information needed, the user would key it into the display, then ENTER it with an appropriate push button. Using a microprocessor, the messages could be entered in random order and their numbers limited only by amount of RAM space provided by the micro.

To provide feedback of the data entry, it was a tempation to try some firmware gymnastics and creative symbol design to allow use of an existing 3-character display on the face of the Sigma HTU. On further reflection, however, the low cost and ready availability of a standard LCD clock display clearly made it the better selection. The fact that, again, it would be less complicated for the user sealed the argument. Moreover, the microprocessor selected for use in the device (a low-current CMOS device) already featured an integral LCD driver. The selected micro also had sufficient RAM space to enable up to 15 events, so there was little danger in any home VCR exceeding the capacity of the cable device. The addition of a DAILY function, contained in memory as a single event, made it doubly unlikely that its capacity would be overwhelmed anytime soon.

To ensure that the user could check what he or she had done, a REVIEW key was added to individually recall every event. A correction key (CLR) allows any one portion of an entry (e.g. the start time) to be cleared and re-entered without rekeying the

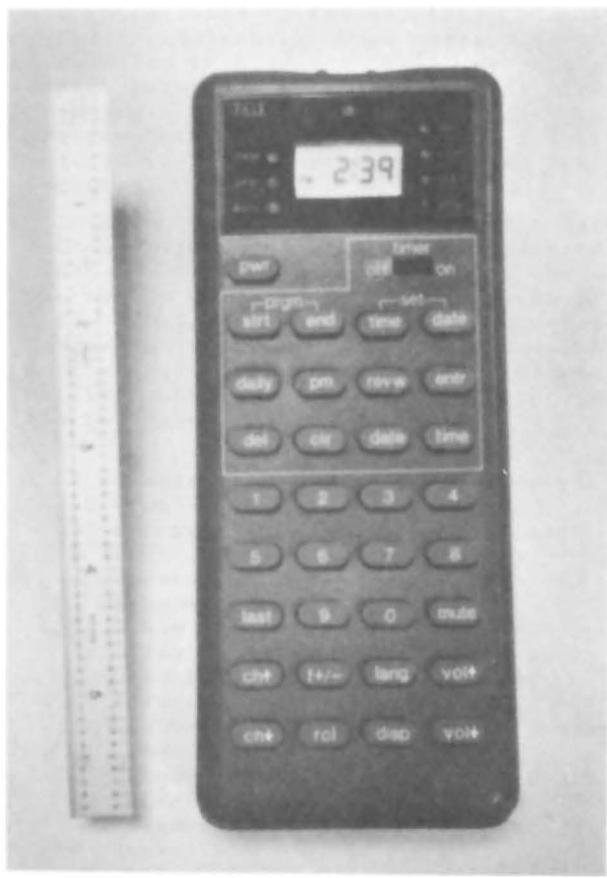

Figure 1. Programmable Remote Control/Timer

entire event sequence. A delete function (DEL) is provided to allow erasure of an entire event with one key stroke. Finally, function keys were added to allow the current date and time to be set or reviewed.

The resulting device, shown in Figure 1, includes a total of 34 controls, seven LED programming indicators, an LCD, and one LED feedback indicator for normal remote control functions. While this sounds complicated in the description, it's less so in the flesh. All timer controls are grouped together at the top of the keyboard while the HTU controls (except for POWER) are at the bottom. The silk-screened outline around the timer functions also helps to guide the user. A custom LCD is in the process of being incorporated which will eliminate the seven status LED's; instead, the written prompt will appear in the display in the appropriate sequence.

So far, the results have been gratifying. When introduced at the Western Cable Show in December 1985, many users who had never seen the device were able to program and operate it even without using the instruction sheet provided. A number of the units are now being field tested in homes of employees and customers (not all of whom are technically oriented) and the reactions of these users, their friends and relatives, are also being compiled. In fact, some additional minor changes (e.g. precise arrangement of buttons) may still be incorporated as a result of this feedback. The initial reception has been sufficiently encouraging that similar devices are now in design for Oak's TotalControl RF addressable terminals.

Notwithstanding this success, however, the Programmable Remote Control Timer must still be considered an interim device. It adds to the growing complement of electronics in subscribers' homes and the very necessity for the device is testimony that the day has yet to arrive when cable-ready home entertainment devices will meet a cable that is ready for them.

ACKNOWLEDGEMENT

Staff Electrical Engineer Arie DeJong led the design of Oak's Programmable Remote Control Timer. Senior Electrical Engineer James Ford Morse was its godfather. The author extends his thanks to both for their help and patience during preparation of this paper.

USER FRIENDLINESS OF BASEBAND CONVERTERS

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ABSTRACT

Making home terminal equipment easier to operate and simpler to incorporate with consumer electronics equipment is an urgent need for the cable industry. The home video/electronics center needs ultimately to be engineered as a whole -- not left to chance, which has been the inevitable result of the different business motivations and technical directions of cable equipment designers and their counterparts in the home electronics industry.

This paper discusses the use of baseband video as the common single element in a systematic approach to the interconnect problem. The "user friendly" operation of the baseband converter is examined in relation to:

- EIA baseband decoder interface
- On-screen display for menu-driven event programming and other user features
- BTSC stereo and audio issues

INTRODUCTION

The most important decisions in the working lives of most cable system engineers are major equipment procurement decisions. Multi-million dollar capital equipment selections are never easy, especially when the factors to be weighed are as complex as in cable plant and component decisions. A good decision can assure a successful system start-up or rebuild; a bad decision can be costly for the system and can wreck a career.

Addressable converter decisions, in particular, can be some of the most agonizing. A commitment to a particular technology is a very long term commitment, sometimes 10 to 15 years. The factors to be considered are very different in character:

- security
- cost
- compatibility
- future growth
- performance history
- supplier profile
- user friendliness

This paper focuses on that overworked but important phrase "user friendliness," as applied to converters, especially baseband converters.

TECHNICAL DISCUSSION

Background

The converter has been around for almost twenty years. Indeed the patent which described the earliest (and still essential) application of the converter to avoid direct pick-up interference (DPU), has run a seventeen year course and expired (Mandell et. al., U.S. Patent 3,333,198, issued July 25, 1967). However the technology has changed radically. In addition to protection against DPU, other functions were added to the converter. It became convenient to use it for channel expansion by tuning non-broadcast channels. With the coming of cable, Pay TV, and scrambling of pay channels, a decoding function was added resulting in the converter/decoder. With an increase in the variety and value of pay services, increased demands have been made on the security of pay TV delivery systems. By the late 70's serious development had started [initially for broadcast subscription television (STV)], of scrambling techniques using baseband video signal processing at both encoding and decoding locations. The application to cable was inevitable and thus emerged the baseband converter.

Later generations of the baseband converter facilitated the intended increase in signal security. It also offered the possibility of increased customer satisfaction by being easier to use than its RF heterodyne forerunner. With access to baseband signals, in particular, audio, it was possible to add volume level to the remote control. Direct access to the baseband signal promised to make it easier to interconnect to a variety of other video equipment, especially VCR's. Other advantages will be realized as consumer electronics video technology matures.

"User Friendliness"

The cable engineer, in making an equipment selection decision, frequently makes a comparison of a variety of converter models from different cable equipment suppliers. Thus in making a comparative evaluation of "user friendliness," the comparison is with other cable converters.

By contrast, the consumer has relatively little experience with other cable equipment, but does have a television receiver(s), and probably has a VCR. The consumer can form both a relative opinion (relative to other consumer electronics equipment), and make an absolute judgement as the converter is used day by day, of how easy and convenient it is to use. And since he makes monthly payments for the services provided via the converter, he also has a way to express his opinion!

To the consumer, "user friendliness" can mean several things, including:

- o functional convenience
- o ease of operation
- o ease of connection to other equipment

Functional Convenience

Functional convenience refers to the kind and type of functions offered by the converter. Channel selection may be by rotary knob, slide-switch or keypad. Interaction between pieces of equipment may be required, for example between the converter and VCR for recording premium programs. The converter may offer remote control, with a few controls such as channel selection and volume control, or with more controls such as those required for a programmable timer.

Ease of Operation

Just providing convenient functions does not necessarily mean that equipment is easy to use; far from it, as most people who have used programmable VCR's will testify. Extremely important to the user are three factors:

- o How obvious is its basic operation?
- o How easy is it to learn to use all the desired features?
- o How easy is it to remember how to use it?

Some features (and for that matter some entire pieces of equipment) are seldom used because of the difficulty of learning and remembering the operation. Ideally, you never have to read a single instruction!

Ease of Connection

The connection between a converter and the home electronics equipment (the television receiver) used to be simple, a short length of RG 59 cable and a balun. With the explosive growth of the use of VCR's, however, the interconnection has become a nightmare involving multiple cables, switching boxes, and dozens of wiring diagrams to choose from. This has become a source of frustration to the consumer and of costly installation and service calls for the operator.

To the consumer, convenience of connection means simple, standardized, interconnections between all types of home video appliances, whether or not they are cable. The consumer ultimately has to be able to shop around for video accessories, and must be able to understand how to connect or plug them together. Equipment configurations, once installed by the operator, must be readily expandable by the consumer, without the need for special accessories (such as switchers).

Benefit of "User Friendliness"

The importance to the operator of the "user friendliness" of equipment installed in the home can not be understated. If the subscriber finds it difficult or inconvenient to connect or use the equipment through which cable services are provided, the end result is always the same; a reduction in the perceived value of the service.

A "user friendly" system will:

- o Assure retention for both basic and pay services.
- o Minimize service calls.
- o Maximize the use of services that are charged on a "per use" basis -- for example, Pay-Per-View (PPV).

Baseband converter technology, by virtue of the very techniques (detailed later) that facilitate enhanced security, also provides the opportunity to increase the variety of easy-to-use functions, and makes possible a standardized interface, ultimately compatible with all video components.

The Baseband Converter

Almost twenty years after their first introduction cable converters still serve an important function in relation to direct pick-up. Channels carried through the cable are still vulnerable to interference by broadcast television signals at the unshielded connection to television receiver tuners. The baseband converter still serves the same purpose of converting such channels (and usually all other channels carried on the cable) to a single output channel not subject to direct pick-up interference. It is almost invariably used to convert all channels carried on the cable, not only non-broadcast channels and pay channels. The consumer uses the converter for all program selections.

Baseband Security

The converter (Figure 1) is constructed with a wide-range tuner which selectively converts any input channel to an intermediate frequency, and then by demodulation to video and audio baseband signals. Baseband signal processing makes possible the use of some extremely secure scrambling/descrambling techniques. The converter illustrated in Figure 1 decodes a scrambled channel which has been encoded by means of:

- o video sync removal
- o video polarity inversion (time variable)
- o digitized encrypted audio transmitted in the horizontal blanking interval (HBI) (2 audio channels)

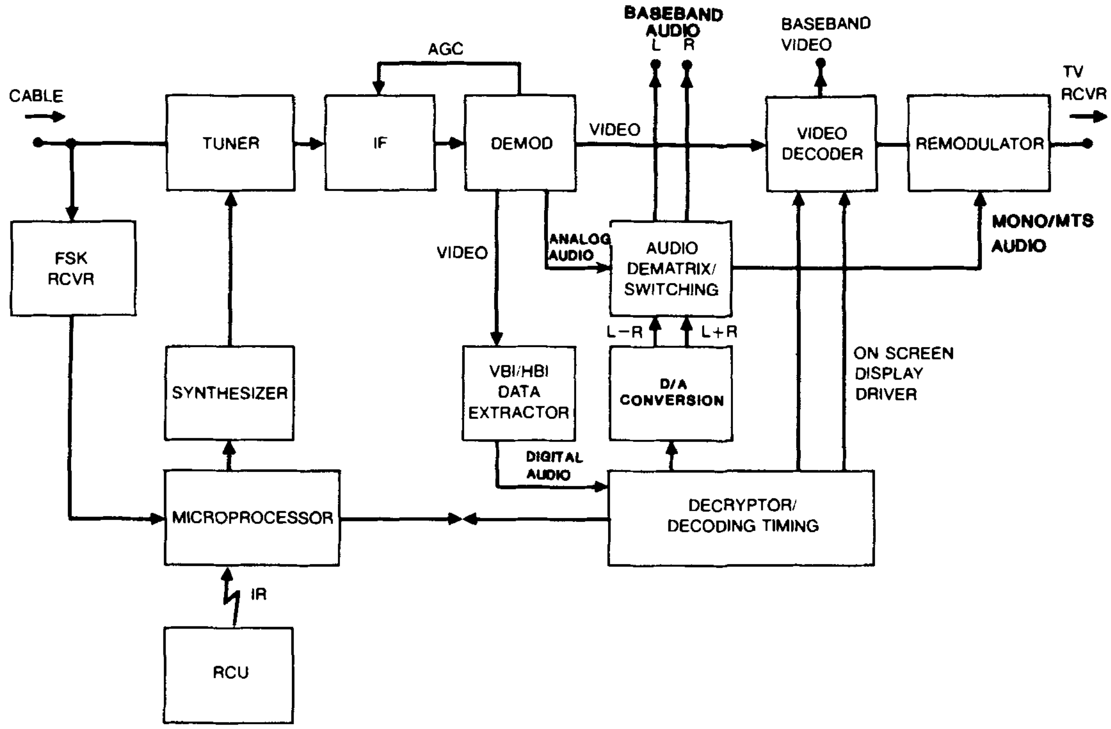

FIG. 1. BASEBAND CONVERTER/DECODER
WITH STEREO OUTPUTS

The audio carrier is not used for premium programs, but is available as a "barker" channel. Addressing is carried out by means of a separate FSK data channel (104.75 MHz or 112.7 MHz). Program identification signals (tags) are sent within the vertical blanking interval of each scrambled channel. All control signals are encrypted for transmission.

Flexibility

This decoder has three kinds of signals accessible at baseband:

- o video
- o audio carried on the audio carrier (including BTSC stereo subcarriers)
- o two channels of audio derived from the encrypted transmission in the HBI.

The use of scrambling techniques employing baseband signal processing for decoding makes possible two developments.

- o the direct connection to other equipment: TV monitors, VCR's, etc. of baseband video and audio signals.
- o baseband-only descramblers for use with television receivers (and VCR's) that are equipped with appropriate interface connectors.

The accessibility of baseband signals implies not only their availability for connection to other equipment, but also the opportunity to modify or substitute other signals for them. Volume (and mute) control of the audio signal is thus made simple. Character generation for on-screen display, is facilitated by access to the video signal and to precision timing signals.

Because the scrambled audio signal is carried as high speed data, the tuner and IF section of the converter are designed for superior frequency response when compared with a television receiver. Used with a video monitor, a baseband converter can avoid the double RF signal processing (and frequency response degredation) inherent in an RF converter connected to a television through the receivers's tuner.

Prior to the announcement of broadcast BTSC stereo, baseband converters were designed to pass only the normal audio spectrum through to the sound carrier of the output channel. Such converters do not pass the BTSC encoded channel. Later generations of baseband converters solve this problem by use of expanded-bandwidth audio demodulator and remodulator circuits.

The availability within the converter of the BTSC subcarriers makes it possible to add an optional BTSC stereo decoder.

On-Screen Display

Because it provides direct access to video signals, the baseband converter provides an opportunity to superimpose additional information on the active video portion of the signal delivered to the television receiver. For this purpose access to video is not the only requirement. The generation of characters to be superimposed upon an active television picture requires precise timing. Timing jitter as small in magnitude as 30 nanoseconds is annoyingly visible. Decoding of scrambled signals requires precise timing circuits, and these same circuits are used to advantage to control the timing of on-screen display characters for both scrambled and clear channels.

It is simple (and cost effective) to provide on-screen display of channel number and time as well as prompting commands and error codes. Upon channel selection the converter/decoder illustrated in Figure 1 displays the channel number followed by time of day (Fig. 2a,b). Each is displayed for 3 seconds, then the display fades from the screen. For minimum cost, display generation circuits are built into the LSI device used for decoding and decryption. The display can be recalled by use of a "recall" button on the converter's remote control unit. The time clock is automatic and is extremely accurate, being periodically downloaded through the addressing channel.

Access to video for generation of superimposed characters can also be used for text display such as teletext, menu-driven-instructions, or captioning, but at additional cost. Instruction screens for such purposes as event pre-programming (time and channel) are becoming available in VCR's, and are likely to become attractive for similar purposes in converters and PPV devices.

The benefits of on-screen display are:

- o easy to read
- o freedom to locate the decoder other than on the television receiver
- o user promoting and the ultimate availability of menu-driven instructions.

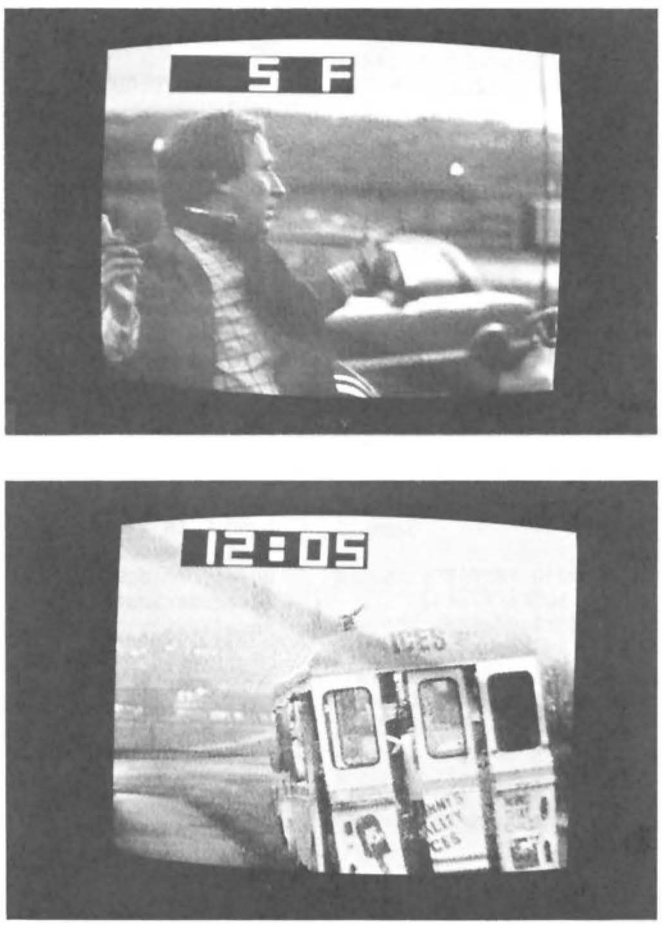

FIG. 2a,b. ON-SCREEN DISPLAY -- CHANNEL NUMBER; TIME

The Baseband Converter and Audio; Opportunities and Challenges

Opportunities. For the baseband converter, dealing with audio, especially stereo audio, provides some unique opportunities and some interesting challenges.

Access to baseband scrambled video makes available an additional communications medium for premium audio. The audio signal can be digitized and encrypted (for very high security) and transmitted as high speed data during the time interval normally occupied by horizontal sync. The result is more audio channels. Two digitized audio channels can be accommodated in the HBI and used with scrambled signals for either stereo or bilingual operation. For stereo the two audio channels are transmitted as (L+R) and (L-R) and are dematrixed in the decoder into left and right baseband audio outputs. The (L+R) channel is retained for the monaural RF output to the television receiver. Bilingual operation uses the two audio channels completely independently with the consumer convenience of remote control selection of either channel. In addition, the normal audio carrier (and BTSC subcarriers if desired) is available for transmission through the cable.

Transmission of premium channel audio as encrypted digital information not only assures the cable operator of a high degree of security, it also provides the consumer the confidence that undesired channels will not accidentally be overheard while tuning scrambled channels with a conventional television receiver.

Control of baseband audio signals in the converter makes available to the consumer the volume control and mute functions that have become very popular with television receivers. The mute function finds additional use in the baseband converter in elimination of the harsh and annoying sounds which sometimes accompany channel changing with RF converters. With an RF converter an interruption of the RF signal to the television receiver is usually experienced when a channel selection is made. The baseband converter provides an output signal continuously; only the video and audio content changes on channel selection.

The baseband stereo outputs of the converter can be addressably controlled for increased revenue. The circuit architecture also provides for a relatively inexpensive BTSC stereo decoder option, also under addressable control.

Challenges. However, besides providing opportunities for improved "user friendliness" and increased revenue generation, the baseband converter has brought a challenge to the designer. Baseband converters were designed only to pass monaural signals to monaural television receivers, the standard at that time. With the later introduction of the BTSC signal format, it was found that baseband converters would not pass the BTSC subcarrier information to stereo-capable television receivers and stereo adaptors.

Manufacturers of baseband decoders have solved this problem by re-designing the converter's demodulator and audio processing circuits in such a way that the BTSC subcarriers can be by-passed within the converter. The output signal will drive a stereo-ready television receiver. There is a degree of compromise however. To achieve volume control without the added costs of stereo decoding and re-encoding, the amplitude of the entire audio signal, including sub-carriers, is varied. In consequence stereo separation varies with volume level. In the converter described here, optimum separation occurs at maximum volume level.

SIGMA Converter/Decoders

To suit various revenue-generation applications, three versions of the OAK SIGMA converter/decoder have been designed:

- SIGMA 1 -- monaural, digitally encrypted.
- SIGMA 3A -- monaural and digital encrypted stereo.
- SIGMA 3C -- monaural/digital stereo and BTSC decoding.

All three versions are designed to pass a BTSC signal through to the RF output terminal. The following table shows the outputs at both RF and baseband terminals for various scrambled and clear types of input signal.

User Benefits

With baseband outputs, direct connection to the consumer's stereo equipment can be provided. In the Spring of 1985 a test was conducted in a large cable system of converter/decoders of the type 3A configuration. Sixty system employees participated, and installed the equipment themselves. Table 2 is a summary of answers to questionnaires completed by a number of the participants.

From the standpoint of "user friendliness" the results were interesting. In order to make use of stereo equipment with the television receiver a significant number of participants had to relocate furniture within the living room. Once having done that, however, most used the stereo to listen to all program material regardless of whether it was stereo or not.

To the consumer, the audio benefits of the baseband converter are:

- volume control and muting
- freedom from channel-change noises
- bilingual operation
- privacy of scrambled channels
- availability of signals to connect to home stereo equipment
- the option of a built-in BTSC decoder so that stereo may be enjoyed without purchase of a stereo TV.

TRANSMITTED AUDIO	SIGMA 1 OR 3A, REMODULATOR OUTPUT	SIGMA 3C REMODULATOR OUTPUT	SIGMA 3A BASEBAND OUTPUTS		SIGMA 3C BASEBAND OUTPUTS	
CLEAR			LEFT	RIGHT	LEFT	RIGHT
MONAURAL	MONAURAL	MONAURAL	MONAURAL	MONAURAL	MONAURAL	MONAURAL
MTS	MTS	MTS MONAURAL OR SAP	MONAURAL	MONAURAL	LEFT OR SAP	RIGHT OR SAP
DIGITIZED/ ENCRYPTED			LEFT	RIGHT	LEFT	RIGHT
MONAURAL	MONAURAL	MONAURAL	MONAURAL	MONAURAL	MONAURAL	MONAURAL
STEREO	MONAURAL	MONAURAL	LEFT	RIGHT	LEFT	RIGHT
BILINGUAL	LANGUAGE 1 OR LANGUAGE 2	LANGUAGE 1 OR LANGUAGE 2	LANGUAGE 1 OR LANGUAGE 2	LANGUAGE 1 OR LANGUAGE 2	LANGUAGE 1 OR LANGUAGE 2	LANGUAGE 1 OR LANGUAGE 2

TABLE 1. SIGMA 1 AND SIGMA 3 OUTPUT MATRIX

		Percent
1.	Did you have problem connecting the converter terminal to TV set?	Yes -- 11 No -- 89
2a	Do you have a component stereo system?	Yes -- 100 No -- 0
b	If yes, did you connect 2 audio jacks to the stereo?	Yes -- 95 No -- 5
c	Is your component stereo located close enough to TV for convenient connection?	Yes -- 68 No -- 32
d	Were 6 foot cables long enough?	Yes -- 56 No -- 44
e	Did you have to move any furniture?	Yes -- 35 No -- 65
3.	Rate degree of difficulty in connecting converter to stereo.	No difficulty ------ 89 Slightly difficult - 0 Moderately difficult 11 Very difficult ----- 0
4a	Did you listen to TV sound using stereo system?	Yes -- 100 No -- 0
	If yes, did you listen to...	All Channels -- 74 Stereo Channels Only -- 26
b	Which channels did you listen to in	MTV -- 47 TMC -- 68
5.	Could you tell the difference between stereo and monaural programs just by listening to the audio?	Yes -- 76 No -- 12 Sometimes ---------- 12
6.	For stereo programs how would you rate the quality?	Very good ---------- 44 Good, better than TV 56 Indistinguishable -- 0 from monaural

TABLE 2. SUMMARY -- SPRING 1985 FIELD TEST

The Baseband Interface

Television receivers are now generally available with the capability of tuning most cable channels. An EIA committee (the Television Systems Committee R4), with help from the cable industry (Ref. 1), has been working on the problem of receiver compatibility with signals which must be descrambled. The committee has defined an interim standard (known as IS-15, Ref. 2) which defines the interface between a wide variety of consumer video devices, with special emphasis on the interface between a television receiver and a decoder.

The approach selected defines a baseband interface in which audio and video signals together with appropriate control busses and an AGC signal are exchanged between the television receiver and a baseband-only decoder. The physical interface is a 21 pin connector known as a Cenelec connector. The receiver and decoder, each equipped with a Cenelec connector, are joined by an interconnecting cable. The connector pin diagram is illustrated in Figure 3. The same interface may be used with other television peripheral devices such as video tape recorders, teletext decoders, DBS decoders, and personal computers.

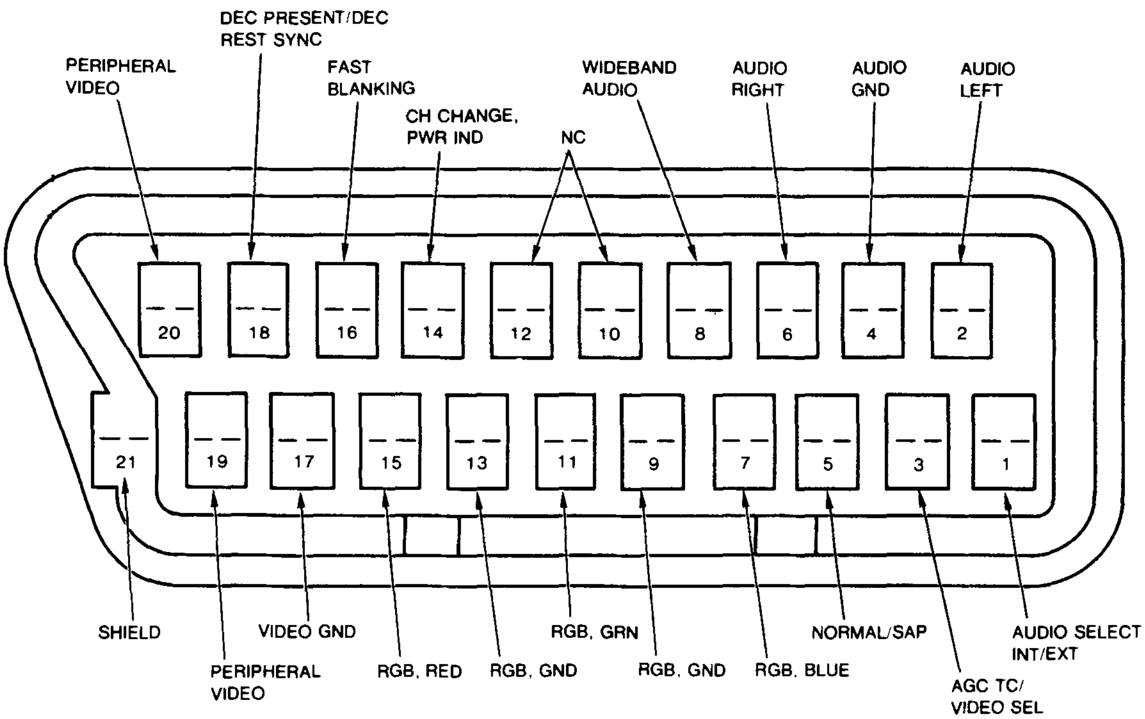

FIG. 3. CENELEC CONNECTOR -- CONNECTIONS

The approach selected is illustrated in Figure 4. Interfacing circuits and the Cenelec connector are added to an otherwise normal television receiver, with all of its customary features. The decoder is much simpler and smaller (Fig. 5) (and less costly) than a converter/decoder; it too contains special interfacing circuits. These circuits normalize the baseband audio and video signals and generate control signals to be exchanged with the receiver.

Channel selection is performed by the tuner contained within the television receiver. Baseband video from the receiver's video demodulator passes through the receiver interface circuit to the decoder. Both scrambled and clear video signals are handled in the same way.

Video received through the decoder interface circuit passes to the video descrambling circuits. The descrambled output is returned to the television receiver in standard NTSC (CCIR-M) format through a similar path.

The decoder determines the status of control signals which are used in the receiver to define the mode of AGC operation, and to select the audio source, dependent upon whether the received signal is clear or scrambled. In the clear mode receiver AGC is developed internally and audio derived from the receiver's internal demodulator. With scrambled signals, AGC is derived from the decoder, and audio may be provided by the decoder if the sound channel is encoded for high security (as illustrated).

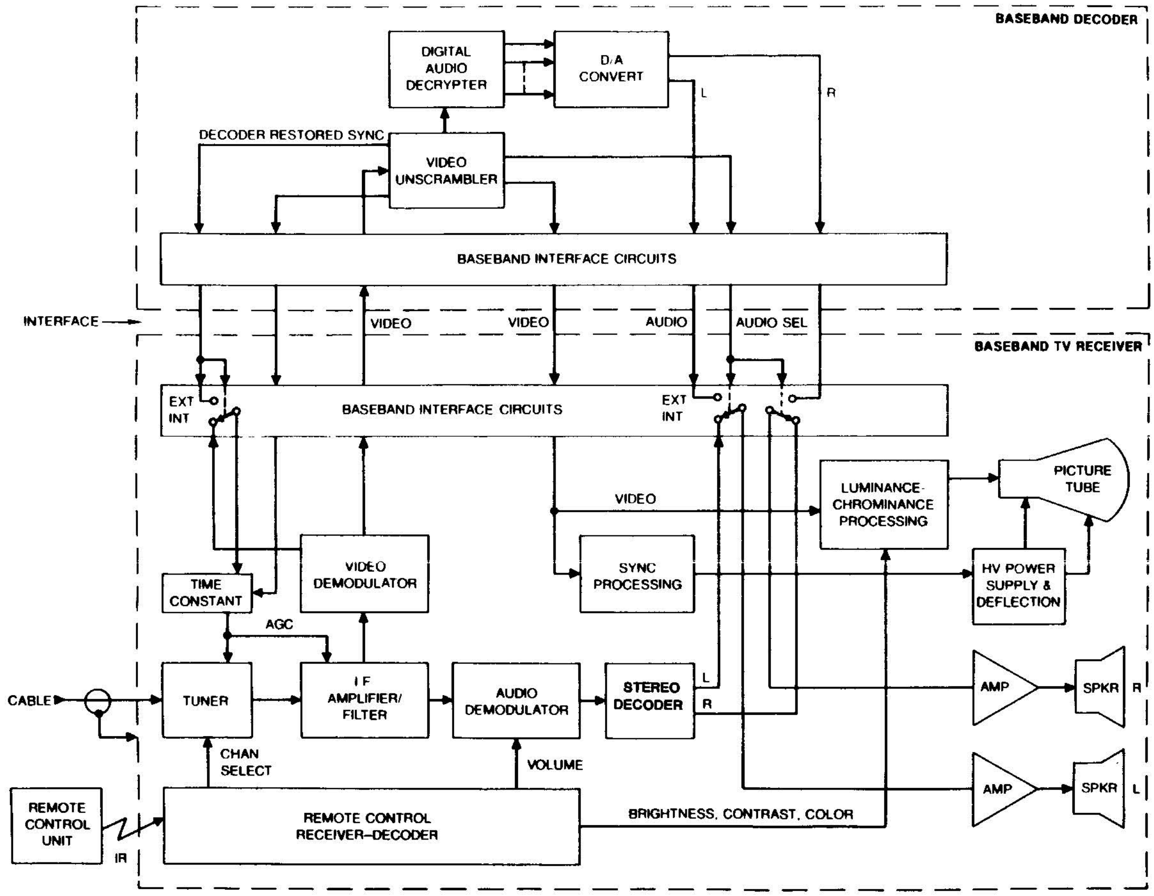

FIG. 4. BASIC BASEBAND CABLE DECODER AND TV RECEIVER FUNCTIONS

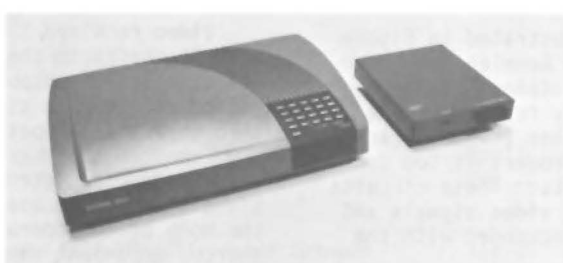

FIG. 5. SIGMA CONVERTER/DECODER AND THE BASEBAND ONLY DECODER

The television receiver/decoder baseband interface makes maximum use of the advantages of baseband scrambling, but with simple interconnection, functional convenience to the consumer, and reduced cost.

The selection of a baseband addressable system is important because of the future availability of baseband-only decoders compatible with the IS-15 interim standard. While RF scrambled signals can be decoded at baseband, and appropriate decoders are likely to emerge (Ref. 2), only baseband scrambled systems can take maximum advantage of the features of IS-15.

With IS-15, baseband video will become the common interconnecting signal format for all components of home video systems including cable devices. IS-15 will benefit the cable operator, who ultimately needs to have less capital invested in fully featured converter/decoders, and the subscriber who will enjoy the ease of installation and convenience of operation. However, as noted in Reference 2, these benefits will only occur if and when IS-15 is adopted and implemented. Cable operators will play a role in providing the incentives to fuel consumer demand for IS-15 equipped receivers, VCR's and other video components.

CONCLUSIONS

In comparison with the RF heterodyne converter, the use of baseband signal processing in a baseband converter provides much superior functional convenience and ease of operation. In making an addressable converter equipment selection decision every key technical factor is in the favor of the baseband system:

- security
- technical development parallel to other consumer video electronics
- interconnections to other equipment

User friendliness is more difficult to quantify than these technical factors. It is also more difficult to put an exact value on it. This paper has attempted to summarize the many ways in which the baseband converter/decoder is demonstrably more user friendly than its RF heterodyne counterpart.

- On-screen Display
  - channel
  - time
  - menu driven instructions
  - eliminates the need to locate the converter on the TV
- Audio
  - bilingual
  - stereo outputs
  - volume control and muting
  - quiet channel changing
  - privacy for scrambled material
- Interfacing
  - stereo
  - compatible baseband-only decoder maximizing the opportunities to interface with other home video equipment
  - baseband video is the ultimate interconnection buss

Ultimately a decision about the "user friendliness" of an addressable converter is a "bottom-line" decision. By influencing customer retention, customer satisfaction (and the effect on service calls), and customer use of equipment for chargeable services, these characteristics of a converter significantly affect the profitability of a cable operation.

In the future the IS-15 interface may permit increased use of addressability with the simpler baseband-only decoder. At that time the economic advantages will be three-fold:

- reduced capital investment
- reduced installation and maintenance costs
- the benefits of increased consumer satisfaction

And who knows? Perhaps the consumer will ultimately own the decoder.

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Using Narrow Band Data Transmission as an Information Delivery System for CATV Applications

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ABSTRACT

The cable industry has in place a highly efficient information delivery system to the home supporting video programming and text. Unknown to many people, the same cable system also delivers one-way data from the cable headend to data receivers in the home disguised as cable TV converters. Many addressable converter systems have been using one-way data over cable for years to address and control the services that are offered by the cable companies. The same technology can be used as a cost effective information delivery system to data subscribers having personal computers in their home.

This paper describes a one-way information delivery system using technology available today. Alternatives to modulation format, addressability and security are presented in detail. In order to help the cable operator better understand the impact of encryption on the cable system, many encryption methods are described along with their impact on the cable operator and cable subscriber. Finally, an addressable system with encryption is described which provides the best trade off between addressability, security and cost.

BACKGROUND

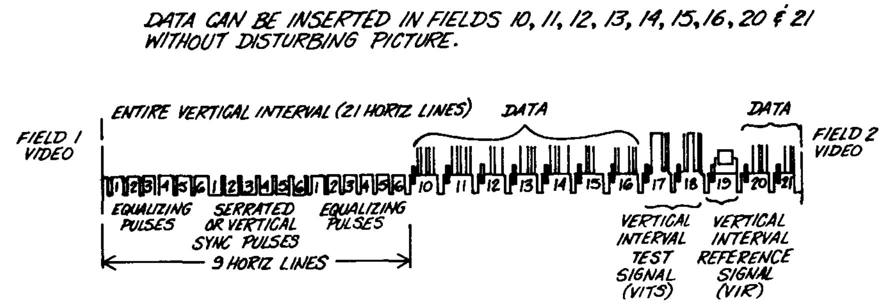
As long as TV's have been available to the budget conscious public, people have been looking for ways to deliver printed information along with the video programming. Early attempts included pointing TV cameras at words printed on a large piece of paper. Technology continued to advance and character generators replaced the cameras and printed page for on-screen text. Now text can be typed directly into a machine and converted directly to a TV signal for broadcast. Computers have found their use in this area by providing large amounts of text storage and by letting the computer decide what text is displayed and when.

WEAK POINTS

Character generators are still used today because they are relatively inexpensive for the cable operator to use and the subscriber only needs a TV to watch both the video programming and text. However, the system has some serious weak points. First, the subscriber must be watching at the time the particular text that he is interested in appears on the screen . Watched video bulletin boards can be very frustrating as page after page of information must be read before information of interest appears. Second, the text uses 6MHz of bandwidth. Now on-screen text must compete with video programming in order for the cable operator to see any merit in its use. Finally, the data is updated very slowly since the user must read through all the information before he finds what interests him. The more text that is displayed, the slower the text can change. And the changing text must accommodate even the slowest reader. Due to the tendency of viewers to lose interest in slowly advancing text, character generated text has had success only with brief messages.

VERTICAL BLANKING INTERVAL

In order to overcome some of these disadvantages, engineers found ways to hide data in the Vertical Blanking Interval ,VBI, of the video programming. The term TELETEXT usually refers to information sent in this manner. An example of data using the VBI is shown in figure 1. The TV paints a picture on the TV screen from top to bottom. When it is finished with one picture it moves the paint brush, or electron beam, to the top of the picture again. The VBI is the time needed for the electron beam to go from the bottom of one picture to the top of the next picture. The VBI has been used for many purposes over the years and no standard has been adopted for its use with



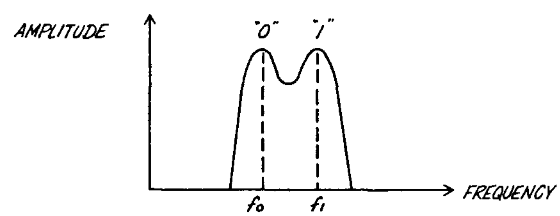
VERTICAL BLANKING INTERVAL WITH DATA

FIGURE 1

data. Using the VBI, thousands of characters of information can be sent in one picture. Unfortunately, the circuitry needed to send and receive information in the VBI is relatively expensive. The data must be separated from the video signal and is coming so fast that it must be stored until it can be seen. And once collected and stored, the subscriber must find some way to display the information.

MODULATED DATA CARRIERS

Modulated data carriers is an alternative to using the VBI. On a modulated carrier, the amount of bandwidth used is a function of how fast the information needs to get to the subscriber. The more the information, the more bandwidth is used [7]. The most popular modulation format for data is Frequency Modulation, or FM. In an FM modulated data signal the data is either a "1" or a "zero", represented by one of two frequencies, see figure 2. The bandwidth is a function of how fast one must switch between the two frequencies and how far apart the two frequencies are set. The circuitry needed to transmit and receive an FM signal is relatively inexpensive.



FREQUENCY MODULATION

FIGURE 2

Computers can talk to one another over telephone lines using this type of modulation. FM modulation also works well on cable TV systems because of its low cost and the small bandwidth it requires. An inexpensive demodulator for receiving 9600 bits-per-second data might use only 200KHz of bandwidth. Less bandwidth is possible by using more costly filters.

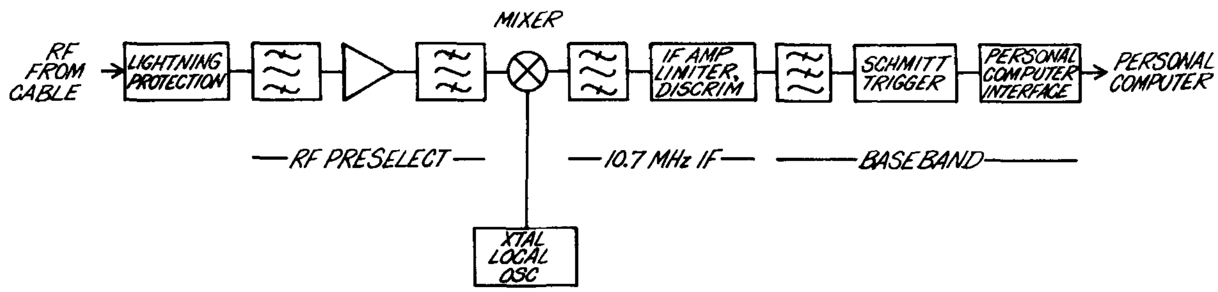
TRANSMISSION RELIABILITY

In addition to data speed and bandwidth, transmission reliability is also important. Different data formats have varying degrees of sensitivity to errors during transmission. VBI is most prone to errors since the information is transmitted as amplitude modulation and is susceptible to many types of noise such as lightning, ingress or poor connections. FM modulation is relatively insensitive to the types of noise typically found on cable systems since the information is sent as alternating frequencies. Limiters in the receiver strip away any influence noise might have prior to data detection. Only noise that interferes with the transmitted frequencies will affect the receivers performance. Addressable converters have demonstrated the high reliability of sending data over cable using Frequency Modulation despite extreme environmental conditions.

Non-addressable Delivery System

NON-ADDRESSABLE SYSTEM FIELD TESTED

Figure 3 shows a demodulator that is being used to receive data over cable. The same design can be applied to data rates up to 64 Kbps by adjusting filter bandwidths and carrier frequencies. Cost and performance were the central goals in the demodulator design. The circuitry uses readily available parts and the performance, measured using a bit-error-rate test set, averaged one error in 10^9 bits with a carrier-to-noise ratio of 20dB. The circuit can be built in an area about the size of a pack of matches. The same circuit was used over the past 12



NON-ADDRESSABLE DATA RECEIVER
FIGURE 3

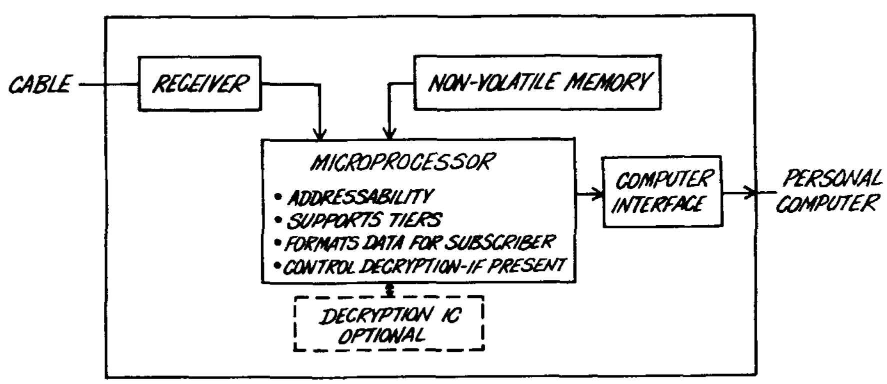
months in several cable systems. The data modulators received data from satellite receivers and modulated the data over cable in the FM band. The data receivers connected directly to the cable and had RS232 interfaces allowing them to be connected to personal computers in the home. Through the system, data was distributed over cable systems to data subscriber's home and the information was collected and displayed on the subscriber's personal computer.

Addressable Information Delivery System

ADDRESSABILITY - PRO'S AND CON'S

For any service provided by a cable operator, the operator must feel confident that he controls who receives the service. This is particularly true when service to a particular subscriber needs to be discontinued. In an addressable receiver, access to the service can be controlled by the cable operator. Once the receiver is deauthorized, the receiver becomes useless until it is authorized once again. Addressability has two major advantages: the cable operator can easily change services or terminate service and the cable operator can charge for tiers of service. Unfortunately, this ability does not come for free. First, the cable operator needs the necessary equipment at the head end to control the receivers, to keep track of who has what authorization levels, and to implement a more complex billing system. Also the cable must be capably of supporting the increased bandwidth needed to pass authorization information along with the data to subscribers. The more authorization and control information that must be sent, the less useful data can be sent to the subscriber.

The main difference between an addressable receiver and a non-addressable receiver is the addition of a microprocessor, (figure 4). The microprocessor does not have to be expensive. Its task is to watch the data as it comes by and look for data addressed to that subscriber. Control data addressed to this receiver is used to load



ADDRESSABLE RECEIVER
FIGURE 4

the authorization tables in the receiver. All authorized non-control data is passed to the subscriber. The same mechanism is present in addressable cable converters and has been for many years. The technology is tested and proven.

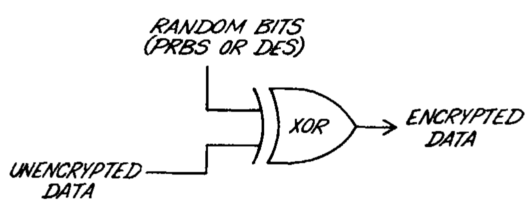
IMPORTANCE OF DATA FORMAT

However, the format of the control data is very important. It must be capable of supporting all the cable operator's current and future needs while keeping the amount of control information to a minimum. Control information gives the cable operator control and flexibility but has no benefit to the subscriber. In fact, it reduces the amount of information he can receive. The amount of control information can be minimized by carefully studying what control is necessary and by using both individually addressed and global commands to the data receiver.

ADDRESSABLE SYSTEM WITH ENCRYPTION

Even with the most sophisticated addressable system, as long as the information is available on cable, people will try to steal it. To prevent data theft, encryption can be used so any information that is received in an unauthorized way is of no use.

There are several methods used to secure data over cable. The most popular technique relies on using a data format that is so unique that no one could "figure it out" or could they? Some manufacturers use unusual modulation formats, others rearrange the bits that are transmitted in a fixed format that is difficult to figure out. Unfortunately, these techniques do not take into account the "hacker" who delights in these types of challenges. And the worst part is that they publish their findings in user club journals and the secret is no longer a secret. Another form of security is by "exclusive ORing" random 1's and 0's with the data before transmission. This is called encryption and is shown in figure 5. The receiver must know how to remove the random data so it can correctly interpret the data it received.

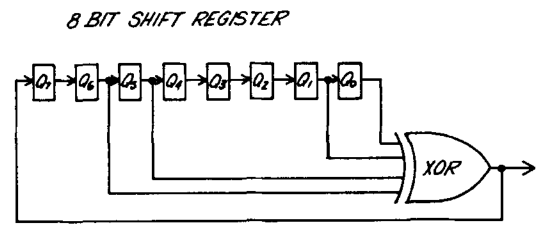


ENCRYPTION

FIGURE 5

TYPES OF ENCRYPTION

There are two types of encryption algorithms commonly used for data transmission: Pseudo-Random Binary Sequences (PRBS) [1,4] and the Data Encryption Standard (DES) [2,5]. The PRBS method of encryption, figure 6, can provide an affective method of encryption when the data changes often and its importance does not warrant an unauthorized subscriber using computers to attack the encryption. Data that has great value such as electronic fund transfer or non-delayed stock quotes require more protection than PRBS



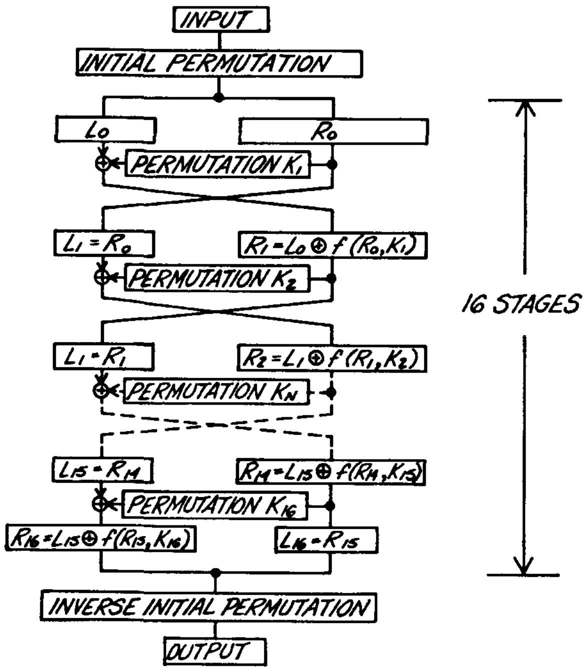
$X^8+X^6+X^5+X+1$ HAS A CYCLE OF 2^8-1 OR 255

PSEUDO RANDOM BINARY SEQUENCE

FIGURE 6

provides. The National Bureau of Standard adopted the DES algorithm, figure 7, for these types of applications. The algorithm can be implemented in either microprocessor software or a single Integrated Circuit containing the DES algorithm. This algorithm is gaining popularity for use in data distribution due to its availability in a single IC. Information Providers wishing to deliver data over cable want as much protection of their data as is available. Even if the DES algorithm is more security than is warranted, the information provider will often ask for it because they equate the name with security. One information provider might require multiple levels of encryption for many tiers of data to the subscriber.

Readers should be aware that the DES IC's are difficult to use. From a list of available DES IC manufacturers [2] we selected one based on its speed and flexibility. A bread board has been built using this chip for applications where security of data is of primary concern. The intent was to design a system where encryption can be added economically as it becomes necessary.



DATA ENCRYPTION STANDARD

FIGURE 7

ENCRYPTION KEYS

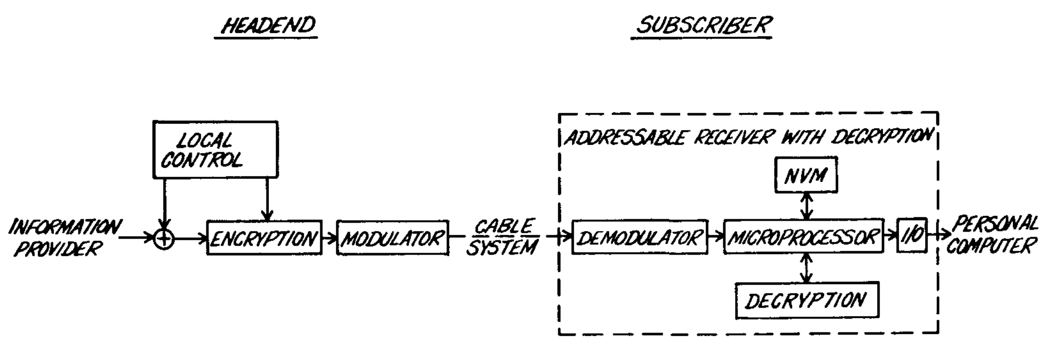
No matter which encryption algorithm is chosen, the data is protected only as much as the encryption key used to create the data [3,6]. Just as a house key provided to a crook bypasses all the locks and window bars, the encryption key unlocks access to the data. Unfortunately, the receiver needs to know the key that was used in the transmitter so it can decrypt the data. So, keys must be sent down the cable to the appropriate receivers. The keys must be encrypted using keys known by both the transmitter and receiver. They should be changed as often as practical. One method used for sending keys requires future keys to be sent encrypted with current keys. Then at some predetermined time or as a result of a global command the future key becomes the current key and the process continues. Both the transmitter and receiver always know which key to use to decrypt data.

ENCRYPTION ON CABLE

An addressable data system with encryption can be added to any cable system as shown in figure 8. The receiver, figure 4, consists of many of the parts that are already in most addressable cable converters. The method of encryption can be any of those already discussed.

ENCRYPTION DATA FORMAT

The data format, shown in figure 9, supports both global and individual commands for controlling authorization, tiers and encryption. It is compatible with the High-level Data Link Control, HDLC, data format. The address information is not sent encrypted so the receiver can identify its data on power up when encryption keys have not been sent. The data field including the authorization data and future key is encrypted using the current key. The address information can be extended by setting the most-significant-bit in the address field or any control field indicting that the next byte is part of the current field. DES was chosen for our method of encryption for maximum protection of data during transmission. The system shown can accommodate a modular evolution from non-addressable to addressable to addressable with encryption.



ADDRESSABLE DATA DELIVERY SYSTEM WITH ENCRYPTION

FIGURE 8

HDLC HEADER (1 BYTE)	ADDRESS (1-N BYTES)	CONTROL (1-N BYTES)	DATA FIELD (1-N BYTES)	FRAME CHECK SEQUENCE (2 BYTES)	HDLC TRAILER (1 BYTE)

ADDRESS	CONTROL FIELD	DATA FIELD
ALL '1' = GLOBAL	ENCRYPTED FUTURE KEY	FUTURE KEY ENCRYPTED WITH CURRENT KEY
ALL OTHERS = NONGLOBAL	ENCRYPTED AUTHORIZATION	AUTHORIZATION LIST ENCRYPTED WITH CURRENT KEY
	ENCRYPTED DEAUTHORIZATION	NONE (ALL AUTHORIZATION TABLES DELETED IN RECEIVER)
	ENCRYPTED NEW USER	CURRENT KEY ENCRYPTED WITH USERS SERIAL NUMBER FOLLOWED BY AUTHORIZATION LIST ENCRYPTED WITH CURRENT KEY
	NONENCRYPTED AUTHORIZATION	AUTHORIZATION LIST WITHOUT ENCRYPTION

ADDRESSABLE FORMAT WITH ENCRYPTION
FIGURE 9

CONCLUSION

As cable operators seek additional sources of revenue from their cable system, delivery of digital data to the home can be a benefit to both the cable operator and subscriber. Information providers continue to explore new ways to deliver their information and the technology is available to use cable as the next frontier. Knowledge of digital transmission methods and encryption techniques can help the cable operator take advantage of the opportunities unfolding in this new digital data frontier.

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